The Commonwealth of Massachusetts.

A REPORT

UPON THE

QUAHAUG AND OYSTER FISHERIES

OF

MASSACHUSETTS,

INCLUDING THE LIFE HISTORY, GROWTH AND CULTIVATION OF THE QUAHAUG (VENUS MERCENARIA), AND OBSERVATIONS ON THE SET OF OYSTER SPAT IN WELLFLEET BAY.

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Massachusetts, from its geographical location as a distributing center and from the character of its shores, is peculiarly endowed for securing an enormous shellfish trade. Recognizing the importance of the shores as a source of food and wealth for the people of the State, a natural safeguard against the excessive cost of living, the Legislatures from 1905 to 1910 directed the Commissioners on Fisheries and Game to conduct a series of investigations and demonstrations to determine methods of developing the shellfisheries. In 1906 and 1907 two preliminary statements were published; in 1909 a general "Report upon the Mollusk Fisheries;" and in 1910 a special "Report upon the Scallop Fishery." The reports herewith presented relate to the "Quahaug and Oyster Fisheries," and will be followed by others on the "Clam Fishery" and the "Food of the Economic Mollusks."

THE LIFE HISTORY AND GROWTH OF THE QUAHAUG (*Venus mercenaria*).

Dr. George W. Field, *Chairman, Massachusetts Department of Fisheries and Game, State House, Boston, Mass.*

Sir: — I herewith submit the following report upon the life history and growth of the quahaug or hard clam (*Venus mercenaria*). All investigations herein are supplementary to those made in accordance with the provisions of chapter 78, Resolves of 1905. The work was conducted by D. L. Belding, assisted by W. H. Gates and C. L. Savery in 1906, W. G. Vinal in 1907, 1908 and 1909, F. C. Lane and A. A. Perkins in 1908 and 1909.

Respectfully submitted,

David L. Belding,
Biologist.

The report on the mollusk fisheries for 1909 presented a preliminary survey of the prevailing conditions in the natural quahaug beds of the Commonwealth, showing by maps and descriptions their extent, condition, present production, and possibility of development under cultural methods. The aim of the present paper is to complete the

investigation by a final report upon the best methods of increasing the natural supply, as determined by a study of the life history, habits and artificial propagation of this mollusk.

Object. — The investigation was conducted with four main objects in view: —

(1) To determine, if possible, a method of successfully raising seed quahaugs on a commercial basis.

(2) To find the rate of growth under various natural conditions and the length of time necessary to raise marketable quahaugs.

(3) To demonstrate the value of thousands of acres of unproductive flats along our coast.

(4) To discover methods of culture which would increase the supply and check the decline of areas now productive.

In order to satisfactorily determine these points it was found necessary to obtain information upon: —

(1) The distribution and range of the quahaug.
(2) The anatomy and its relation to the habits of the animal.
(3) The spawning, early life history, reproduction and propagation.
(4) The habits of both young and adult.
(5) The rate of growth.
(6) The quahaug fishery, — its present extent and possibilities.
(7) The cultivation of quahaugs.

As it is the purpose of this paper to present a complete account of the quahaug, it has been frequently necessary to reprint previous works as well as to present new material. No claim for originality is made for the portion on anatomy, which is largely a popular revision of Kellogg (1), (2),[1] and of a laboratory manual by Prof. Gilman A. Drew at the Marine Biological Laboratories, Woods Hole.

Courtesies. — The writer is deeply indebted to Dr. George W. Field for his general supervision and helpful advice in the investigation and in the preparation of the report; to Prof. James L. Kellogg of Williams College for preliminary instructions and kindly encouragement; to the quahaug fishermen of Massachusetts for their ready co-operation; and to Mr. L. D. Baker of Wellfleet for laboratory facilities. Specially does he wish to commend the work of his assistants, F. C. Lane and W. G. Vinal.

INTRODUCTORY.

More general knowledge concerning the quahaug should be spread abroad among the consumers and the fishermen, as the future of the quahaug industry of Massachusetts lies in the hands of her voters, and only by public sentiment can suitable laws be obtained for the preservation of the mollusk fisheries. At the present time relatively few people in the Commonwealth know anything about the quahaug, except that it lives in the mud and can be gathered with rakes. But three papers have been written upon the quahaug from a scientific or commercial

[1] The numbers after the author's name refer to the bibliography preceding the index.

standpoint. Ingersoll (8) gives an account of the fishery in 1880; Krause (5) made a preliminary outline report for the Rhode Island Commission of Inland Fisheries; and Kellogg (2) published in 1903, under the auspices of the Museum of the State of New York, the first report on the feeding habits and growth of the quahaug. Unfortunately, this important paper, in which the practical importance of quahaug culture was pointed out for the first time, is little known to the fishermen of Massachusetts. With the consent of Professor Kellogg his report was taken four years ago as a basis for this investigation, and the results here given are a continuation and an expansion of the work originally outlined by him in 1903.

Commercial Experiments. — Our aim has been to make the work thoroughly practical, and it has been undertaken scientifically because science offers the best means of approaching any practical problem. The essential aim has been to develop scientific methods for the extension of the commercial quahaug fishery.

General Results. — Four years of experiments have demonstrated with convincing force that the only method of permanently increasing the natural supply, which can be applied on a large scale, is artificial culture or quahaug farming. The quahaug grows with sufficient rapidity to warrant large returns from small capital. Many acres of unproductive flats can be turned into valuable quahaug gardens, and many men given employment by the institution, under proper legal regulations, of a system of individual leases for the planting of quahaugs. Aside from its remunerative possibilities such a system is the only means so far devised for permanently checking the decline of the natural beds.

The Quahaug Family. — The quahaug belongs to the class of mollusks called the *Lamellibranchia*, or, to use an older nomenclature, the *Pelecypoda*. According to the classification given by Pelseneer (6), in which lamellibranchs are classified by their gill structure, the quahaug is placed with the soft clam (*Mya*) and the sea clam (*Mactra*) in the class of the *Eulamellibranchia*, one of the four great orders of the lamellibranchs, which is characterized by the edges of the mantle being generally united by one or more sutures, the presence, as a rule, of two adductor muscles and the union of the gill filaments at regular intervals by vascular junctions. In addition to the many living species the subfamily to which the quahaug belongs is represented, according to Zittel (10), by many fossil forms, extending from the Jurassic to Recent.

On the New England coast, according to Gould (11), two species, *V. mercenaria* and *V. notata*, with possibly a third, *V. præparca*, more generally considered a variation of *V. notata*, are found. Of these forms, *V. mercenaria* is the most abundant, and the other two are often considered as local variations of this species.

Names. — The scientific name of *Venus mercenaria* is supposed to

have arisen from the use of the shell as "black wampum" by the Indians, as the beautiful purple tinge on the inner side of the shell made it an object of exchange among that primitive people. The common name in the New England States is "quahaug," sometimes spelled "quohog" or "cohog," while in New York and the south, where the soft clam (*Mya arenaria*) is not abundant, it is known by the name of "clam," "hard clam" or "hard-shelled clam." The small quahaug goes by the commercial name of "little neck," probably to distinguish it from the long-necked clam, *Mya,* although the claim is put forward that it was originally a local name similar to the "Blue Point" with the oyster. Ingersoll (8) states that in New Jersey they call small quahaugs, only an inch or so in breadth, "tea" clams. The present names are probably derivations of the old Indian names, such as "Poquahock," as given by Roger Williams in "A Key to the Language of America." Occasionally the monosyllable "quog" is used. The pronunciation of the word quahaug varies with the localities.

Distribution. — The quahaug, while essentially a southern and warm-water form, is found along the Atlantic coast from the Gulf of St. Lawrence to the Gulf of Mexico, where it was reported by Kellogg (3) in the vicinity of the Chandeleur Islands in 1904. Attempts are now being made to develop the fishery in Louisiana, but there is small demand for this shellfish in the local market. *Venus mercenaria* is truly an American form, its natural habitat being the Atlantic seacoast, although a few are reported to have been found in the last few years on the Pacific coast, as the result of accidental transplanting with eastern oysters.

In Massachusetts the quahaug is confined to the region of Cape Cod and the southern waters of the Commonwealth, practically no specimens being found north of the Plymouth section. As can be seen from the distribution map (Fig. 30), a few quahaugs are found in Massachusetts Bay except on the north side of Cape Cod. The same state of affairs exists along the Maine coast, except in a few sheltered bays, such as Quahaug Bay, where the warm water and favorable natural conditions are such as to preserve the remnant of a once great quahaug supply. There is also evidence that a few were formerly taken near Salem, Mass. Passing northward, the quahaug again becomes abundant, and is found, according to Gould (11), at Halifax, Sable Island, Prince Edward Island, on the fishing banks and in the Gulf of St. Lawrence. At the present time a considerable number of small quahaugs of peculiar color, shape and flavor are shipped from Prince Edward Island. The present distribution, the geological changes along the coast and the evidences of former abundance, such as Indian shell heaps, are evidence, submitted by Ingersoll (8), that years ago the quahaug was more widely distributed, and that possibly on account of a decrease in the temperature along the shore of Massachusetts Bay there occurred a corresponding decrease in the supply and distribution of this mollusk.

Thus we find that the quahaug has retreated southward, Cape Cod at the present time marking, with the exceptions above noted, the northern limit of its range. In the warm waters of coast States in the south, where the quahaug develops more rapidly, there are large areas which as yet have not suffered from the effects of overfishing, as has been the case with the northern beds in New England and New York, but it will be only a short time before the history of ruthless spoliation will be repeated, as already quahaugs from the south are being shipped to the New England markets. Commercially in Massachusetts the hard clam is found both on the north and south side of Cape Cod and in Buzzard's Bay, the principal fisheries being at Wellfleet, Eastham, Orleans, Edgartown, Nantucket and in the Buzzard's Bay villages.

The same natural conditions which suit so well the shallow-water scallop (*Pecten irradians*) are also adapted to the growth of the quahaug, which is found on the sandy and muddy flats just below low-water mark, although occasionally occurring between the tide lines, particularly on the north side of Cape Cod where the great fall of the tide exposes a large area of flats. On the southern coast of the State it is mostly confined to the sheltered bays and inlets, in contrast to its more exposed conditions on the north side of Cape Cod. Owing to its natural adaptability for existing on nearly every kind of bottom, and its extensive range from high-tide line to a depth of over 50 feet, nature has provided the quahaug with a vast territory, of which the commercial fishery possesses only a small part. Scattering quahaugs are found over the rest of the area, but in paying quantities only in limited places. The possibilities of developing this great natural tract of quahaug ground are especially alluring — far more so than any of the other shellfisheries. The quahaug has a greater area, greater possible expansion and a more profitable market. Nature has equipped the numerous bays of southern Massachusetts with remarkable facilities for the production of quahaugs; it only remains for man to make the most of these advantages.

Methods of Work. — The work was conducted along three main lines: (1) a microscopical study of the early life history, including spawning, reproduction and hatching, mostly carried on by laboratory methods; (2) observations as to habits and distribution, both by laboratory experiments and by a biological survey of the quahaug territory; (3) growth and cultural experiments by means of about 187 small beds planted under a variety of conditions in the different waters of the Commonwealth. The methods of work are later described in full under each section.

Experiments have been conducted from 1905 to 1909 chiefly at two localities, (1) Monomoy Point on the south side and (2) Wellfleet harbor on the north side of Cape Cod, which represent the two classes of quahaug territory in Massachusetts. The Monomoy experiments, particularly growth, have been continued for the entire period, while

the Wellfleet investigations have been conducted only for the two years of 1908 and 1909. Owing to the necessity of concentrating the work, and from the variety of natural conditions obtainable in these two localities, particularly in Wellfleet harbor, the greater part of the work was confined to these sections. The work in other parts of the coast during this period comprised growth and cultural experiments at Plymouth, Monument Beach, Nantucket, Essex and Ipswich; determinations of the food value of the waters in the different quahauging localities; and a biological survey of the natural quahaug beds in the Commonwealth.

Excellent opportunity for the study of the life history and growth of the quahaug was afforded at Monomoy Point by the Powder Hole, formerly a harbor capable of sheltering many fishing vessels, but now little more than a small enclosed body of water connected at high tide with the ocean by a shifting channel. This natural aquarium of several acres, teeming with shellfish life, was leased for experimental purposes by the Commonwealth, and proved, by its protection and variety of natural conditions in a limited area, a most satisfactory location for the quahaug investigation. In 1906 a small shanty was fitted up as a laboratory, and a raft 20 by 10 feet was anchored in the deeper water of the Powder Hole. Growth experiments for a period of four years were conducted by suspending boxes of sand from the raft at various depths, while several methods of spat collecting were tried. In the flats and waters of the Powder Hole, under different conditions as regards current, soil and depth of water, a number of cultural experiments were established.

The conditions at Wellfleet were quite different. The harbor, some 5 miles long and nearly 2 miles wide, containing nearly 2,500 acres of quahaug ground, presented a wider and more diversified field than the limited area at Monomoy. Owing to its great rise and fall, averaging 10¾ feet, the tide sweeps in and out of the harbor with great swiftness, giving to the shellfish beds, particularly in the lower part of the bay, an excellent circulation of water, and laying bare at low water a vast area of flats. Quahaugs were found over most of this area both between the tide lines and beyond, in water ranging from a few feet to 50 feet at low tide, particularly in the channel. This section of the coast may be considered the home of the quahaug, as a large share of the total production of the Commonwealth comes from these waters. Consequently, it seemed particularly fitting that, after the preliminary experiments at Monomoy Point, this locality should be selected as the best field for the more extensive cultural experiments of 1908 and 1909. Through the kindness of Mr. L. D. Baker of Wellfleet a building was furnished for a laboratory, which served as a central headquarters for the shellfish work, and from its situation on a wharf over the water offered excellent opportunities for hatching and reariug experiments.

ANATOMY.

A description of the anatomy necessarily should be included in a report on the quahaug, as a knowledge of the general structure of the animal is essential for the proper understanding of its development and habits. Just as certain words not in everyday use by most people are found convenient to sailors, printers, mechanics and men in any occupation, so a biologist must make use of certain technical terms in his descriptions. Those used in this report, however, are not numerous and not hard to remember. They are as follows: anterior, posterior, dorsal and ventral. The two former correspond to the terms "fore" and "aft" as used by sailors. In a quahaug the anterior is the end in the direction of which he burrows, the end from which the foot protrudes. The posterior or rear end is that at which the siphon or "neck" is located. This seems a little odd, but is easily understood when we recall that the prefix "ante" means before and "post" means after. In a quahaug the dorsal side corresponds to the hinge, the ventral to the side on which the shell opens.

It is the belief of biologists of the present time that all animals of a similar kind are descended from common ancestors. Thus, the clam, oyster, quahaug, scallop, mussel, etc., are believed to have a common descent, as their early development is strikingly similar. Of these forms there is reason to believe that the quahaug most closely resembles the common ancestor. The study of this typical shellfish is, therefore, especially interesting.

The Shell. — The quahaug shell is formed of two heavy valves, equal in size and curvature, which enclose the soft parts and may be drawn tightly together for protection. The two valves are joined together on the upper or dorsal side, the hinge line, by a dark elastic ligament surmounting on each side a row of teeth, which fit into corresponding depressious in the opposite valve. This ligament gives the shell a natural tendency to gape, which is offset by the action of the two adductor muscles in bringing the edges in close apposition. The shell of the adult quahaug measures slightly more in length than in width, the average dimensions being: length, 3 inches; width, 2⅝ inches; thickness 1⅝ inches. All sizes, weights and forms can be found, depending upon age and environment. Owing to the thickness of the shell distortion is not as common as with the scallop and clam, and few deformed specimens are found. The largest quahaug known to the writer was taken in a scallop dredge off Harwichport, and measured 5¼ inches in length.

The most prominent features of the external surface are two swellings, the umbones, one on each valve, which are directed anteriorly and toward the hinge, forming the so-called beak. Many specimens show imperfect umbones, due to the wearing away of the lime. Just beneath

the beak is a depression, the part on each valve having the shape of a half moon, called the lunule, which is characteristic of the quahaug. The surface of the shell is covered with numerous concentric lines of more or less prominence, forming thin, closely packed ridges at the anterior and posterior margins, and leaving the lateral portion of the shell smooth. These ridges are more prominent in the young and rapidly growing quahaugs than in the large specimens, but they appear too irregularly and too frequently (75 to 100 on an average specimen) to be of any value in determining the age of the quahaug. In old age these growth lines pile up, showing retrogressive development, so well illustrated in the case of "blunts," where growth consists merely in a thickening of the edges. The shell is naturally free from foreign growth, although old specimens are sometimes found with shells honeycombed by the boring sponge, and quahaugs which are out of the sand are often covered with Serpula, barnacles, silver shells, grasses, etc.

On examining the interior of a valve, one sees a rough, white surface dotted with small granules between two large oval impressions, which mark the attachment of the adductor muscles. The ventral borders of the adductor muscle scars are connected by a distinct line, the pallial line, which is formed by the attachment to the shell of the mantle, a large flap forming the outer part of the body of the quahaug, and separates the white granular portion from a narrow, smooth, shiny surface, sometimes of a purple color. The posterior end of this line is indented to form the pallial sinus in which lies the siphon or neck. Just above the attachment of the adductor muscles can be seen smaller impressions, to which the muscles for moving the foot are attached. Along the hinge line are two kinds of prominent teeth, — the anterior or cardinal, consisting of short elevations; and the posterior or lateral, which extend for some distance along the dorsal margin. These teeth fit into corresponding depressions in the opposite valve, interlocking to form a compact joint. On the margin of the valve are faint vertical elevations which give the inner side a milled effect, as on a coin.

The shell is made almost entirely of lime, in some specimens crumbling on pressure in the hand. When dry quahaugs are handled in numbers, as in the shipping houses, considerable dust arises from the fine particles of lime which are rubbed off the shells, and if these quahaugs are again placed in water a white color is imparted to the fluid. Quahaugs from different localities vary in the hardness, compactness and thickness of shell, evidently due to the different amount of lime in the water. There are three layers, a rough outer, a fine middle and a thin, smooth inner, the outer being formed by the edge of the mantle, the two inner by secretions from its sides. In external appearance the shell varies from a white to a blue gray, according to the soil in which the animal is found. The heavy shell, so well adapted for the protection of the animal from enemies, makes it an almost stationary form, although it undoubtedly has the power of locomotion.

The Mantle. — The inside of both valves is closely lined by thin, semitransparent mantle lobes, which enclose the body in a fleshy case when the shell is shut. The enclosed space is called the mantle chamber. These folds are united on the hinge line, and are attached to the upper part of the visceral mass, the gills and the adductor muscles. The free border of each lobe is thickened, of white or yellow color according to the age of the quahaug, and folded into a double row of delicate frills. It contains slender muscle fibers which are attached along the pallial line of the shell. The edge of the mantle possesses sensory or tactile organs, as is shown by the withdrawal of the mantle when touched by a foreign body. The consumer can determine whether he is partaking of live or dead shellfish, as only the living form will respond in this way.

The function of the mantle is sensory, protective, respiratory, and assists in feeding. It forms a reservoir for the blood, and secretes, by numerous gland cells on the outer side and edge, a sticky substance which becomes impregnated with lime to form the new shell layers. Other cells at the edge secrete the horny cuticle, which can sometimes be seen reflected over the outer edge of the shell.

The Siphons. — On the posterior border the lobes are joined together in the form of two tubes, which are known as the siphons, or more commonly as the neck. The siphon is longer and more prominent in the soft clam (*Mya*), and the smaller fleshy extension of the quahaug is not so noticeable. Water passes in at the larger or lower opening and leaves by the smaller or upper, in this way establishing a continual circulation of microscopic food. The muscles of the siphon are heavier than those of the other part of the mantle, and form a V-shaped attachment to the shell, the pallial sinus. The siphons are yellow in color, often tinged with pigment, and bear very minute tentacles upon the outer edge, especially on the incurrent. The waste products are extruded into the stream of water passing out the excurrent siphon.

The Foot. — The quahaug has a large muscular foot resembling a plowshare, or a boat's keel, which can be thrust outward between the folds of the mantle. Its action is controlled by retractor muscles, anterior and posterior, which are attached to the shell above the adductors, and by the distention of the foot with blood. Although the shape of the foot is suggestive of a crawling existence, the quahaug makes but little use of this habit. Occasionally a groove can be seen in the sand where the quahaug has traveled a short distance. For the most part the foot is used as a burrowing organ, possibly because the heavy shell renders traveling difficult.

The Gills. — The foot merges into the abdominal portion or visceral mass, on each side of which are two conspicuous folds, the inner and outer gills, which hang free in the mantle chamber as delicate curtains between the visceral mass and mantle. The outer gills are attached at their base to the inner, which in turn are attached to a part of the

visceral mass and to the inner gills of the opposite side, dividing the mantle chamber into a larger ventral and a smaller dorsal portion, the branchial and cloacal chambers respectively. Through the gills water is passed into the cloaca, and is forced out of the upper or excurrent siphon, which is in direct connection with this chamber, while the incurrent siphon leads only into the lower apartment. The gills may be roughly compared to sieves, by which the solid particles, including the minute plants, on which the quahaug feeds, are strained from the water.

The general structure of a gill is excellently described by Kellogg (2): —

The gills are the most complicated organs in the bodies of lamellibranchs, and must be described here as briefly and as simply as possible, without mentioning their wonderful histological structure. Outer and inner gills are practically the same. Suppose that one of these is carefully removed from its line of attachment to the body, and studied by means of the microscope from the surface and in section; such an examination shows the gill to be not a solid flap or fold, but an exquisite minute, basket-like structure with an outer and inner wall inclosing a space between. These walls are made of extremely fine rods placed side by side. In order that these rods may retain their position, they are in many forms irregularly fused with each other by secondary lateral growths of tissue. The outer and inner walls of the gills are also held together by partitions which extend across the inner space between them. The gill is thus seen to be basket-like, the walls being made of rods between which are spaces, which put the interior chamber in communication with the mantle space in which the gills hang. These rods, or filaments, of which the gill is made, contain an interior space into which the blood flows. They were probably primarily developed in order that the blood of the body might be brought in close contact with the water, that, by diffusion, the carbon dioxide of the blood might pass outward through the thin walls, while, by the same process, oxygen, carried by the water, might pass into the blood. But, in addition to performing the function of breathing, the gills have taken on that of collecting minute organisms used for food.

The Digestive System. — Just behind the anterior adductor muscle on the anterior part of the body is a funnel-shaped opening leading into a more constricted tube, the œsophagus. The mouth is guarded by two pairs of delicate ciliated flaps, triangular in shape, tapering backward toward the anterior part of the gills. These organs are the labial palps, which perhaps may be likened to the lips of higher animals, the two outer uniting to form the upper lip, the two inner the under lip, and have the power of conducting the microscopic food to the mouth. The œsophagus leads back into the stomach situated close to the dorsal wall of the visceral mass and surrounded by the liver, a paired dark-brown gland, which secretes the digestive juices. The intestine leads from the stomach in the form of a narrow tube, which, after making several

convolutions in the visceral mass, passes backward through the heart to end just over the posterior adductor muscle.

The Circulatory System. — The blood of the quahaug is a colorless liquid passing in definite channels over the whole body, bringing oxygen and nourishment to all the tissues, and removing the waste materials. The chief organ of circulation, the heart, is situated on the dorsal part of the body, posterior to the stomach, in a large triangular pericardial space. It consists of an anterior ventricle and two auricles, which have a filmy appearance. The intestine passes through the ventricle. Blood is pumped from the ventricle through two aortæ, anterior and posterior, to the various parts of the body, whence it is returned to the gills, and thence to the auricles, which open into the sides of the ventricle.

The Nervous System. — The principal nervous mechanism of the quahaug consists of three pairs of ganglia. The first pair, the cerebral, are little white round organs about the size of a pin head, situated on both sides of the mouth, just posterior to the anterior adductor muscle, and are connected by a thin commissure which passes anterior to the œsophagus. Two other commissures pass from each cerebral ganglion, one to join the visceral ganglion of the corresponding side, the other to the pedal ganglion. The visceral ganglia, pear-shaped bodies, lying just beneath the posterior adductor, are also connected by a short commissure, and supply nerves to the mantle, gill and adductor muscle. The pedal ganglia, also connected with each other and with the visceral and cerebral, are situated just dorsal to the muscular part of the foot.

The Excretory System. — The excretory organs, the nephridia, consist of dark colored tubes of glandular nature lying beneath the pericardial chamber, one on each side of the body. By one end these tubes open into the pericardium, by the other, outside the body at the base of the gills. Their function is essentially the same as the kidneys in higher animals, — the extraction of waste material from the body through the blood.

The Genital Organs. — In both sexes the light colored reproductive organs are situated in the visceral mass, just dorsal to the tough foot, where they surround the folds of the intestine, extending upward to cover part of the liver and downward into the cavities of the foot. Kellogg (1) says: "In Venus the generative gland penetrates into spaces between the uppermost bundles of the foot, as is usual in forms with a locomotor foot. The posterior part of the visceral mass has many scattered muscle bundles, generally transverse, running from one side to the other. The sexual gland pushes down among these muscles for a considerable distance." These organs open by small ducts, one on each side, which terminate close to the opening of the excretory system, beneath the free border of the inner gill. The ovaries and testes are usually white, but in older quahaugs, particularly "blunts," they have a somewhat reddish or yellow appearance.

THE EARLY LIFE HISTORY.

Ripening of the Reproductive Organs. — During the spring the ovaries or testes of the quahaug enlarge in preparation for spawning, and the visceral mass assumes a plump appearance, due to the accumulation of numerous eggs and spermatozoa. Just when the first formation of the sexual products takes place is not known, but presumably they are in process of development for several months previous to the time of spawning.

Method of determining the Sex of a Quahaug. — As described under anatomy, the sexes are separate, each quahaug probably remaining either male or female, such as it may be, all its life. During the spawning season the male can be distinguished from the female by an examination of the spawn without the microscope. As this process may be of interest to the fishermen, since it applies to all shellfish, it is here described. The quahaug is opened, the sexual organs sliced with a knife, and the spawn, after diluting with water, is spread in a thin layer on a piece of glass. If the animal is a female, this white fluid will be made up of a great number of minute specks, individually visible to the naked eye, — the eggs: if a male, the fluid will be of a uniform consistency, and will have a milky vibrant appearance, due to the invisible spermatozoa.

The Egg. — The mature egg (Fig. 1), when extruded into the water, is spherical in shape and surrounded, for protection, by a gelatinous membrane three times its diameter. The shape and size of the eggs vary somewhat, even in the same quahaug. Normally they are spherical, though occasionally one axis is slightly longer than the other; but when extruded in masses they possess irregular shapes, owing to the pressure within the ovary. This is especially noticeable in eggs cut from the ovary, and is exceptional in the natural course of spawning. Such eggs soon assume their normal shape in the water. The diameter of the average egg is $\frac{1}{12.8}$ of a millimeter ($\frac{1}{325}$ of an inch). The color of the egg as seen by the naked eye, in mass or separately, is white. Under the microscope it has an opaque appearance, due to the yolk granules, which are packed closely in the cytoplasm. The egg is surrounded by a definite thin membrane, especially noticeable when the polar bodies are formed, differentiating it from the scallop egg.

The large gelatinous covering constitutes a distinguishing feature in differentiating the quahaug egg from other forms, as it forms a transparent film around the egg. Evidently it is formed of a substance which swells when coming in contact with water until it attains about the size of $\frac{1}{102}$ of an inch, or 3.2 times the diameter of the egg. In observing through a microscope eggs which have been artificially fertilized by mixing with spermatozoa, a few eggs will be found free

from the covering, the majority surrounded by it, and sometimes empty cases. Usually a single egg is found in a case, but occasionally two eggs may be found in the same covering. In such instances the eggs are separate and of unequal sizes. The spermatozoa can be seen in great numbers clinging to and wiggling about the transparent film. It is interesting to note that apparently no distinction is made between the gelatinous coverings containing eggs and those without, indicating that possibly the covering and not the egg proper has the power of attracting and retaining the spermatozoa. The only noticeable difference is the absence of an inner or more dense covering, which is differentiated from the outer, when the egg is contained, by the number of spermatozoa which work their way to this second barricade. The cases without the eggs do not have this second layer.

The capsular covering is also of use to the quahaug as a means of protecting the minute egg and of preventing its sinking to the bottom. Only when the eggs are discharged "en masse" do they sink. These floating bits of protoplasm, although more easily washed ashore in rough weather, are carried farther, and do not stand as great a chance of an early death by falling on poor soil, as, for instance, the scallop eggs.

The Spermatozoön. — The spermatozoön, or male cell (Fig. 2), is composed roughly of two parts, a wedge-shaped head, the longest diameter of which, the length, is about $\frac{1}{12}$ that of the egg, and a long, whiplike tail, the motile part. Nature has so arranged in all life that the egg contains the yolk or nutriment, and is therefore the large stationary form, while the spermatozoön, as a specialized organ of locomotion for finding the egg, has thrown off all useless cell contents. The average size of the spermatozoön is: body $\frac{1}{150}$ of a millimeter by $\frac{1}{600}$ of a millimeter ($\frac{1}{3,800}$ by $\frac{1}{15,200}$ of an inch); tail, $\frac{1}{20}$ of a millimeter ($\frac{1}{500}$ of an inch) in length. Often, variations, such as the reversed shape of the head, described by Kellogg (1), are found.

Spawning.

Spawning can best be defined as the discharge of eggs from the female or of spermatozoa from the male into the water, where fecundation takes place by their union. The sexual cells are extruded into the mantle chamber and are carried out the excurrent siphon in a fine stream, passing into the water by successive puffs. A female quahaug was observed to shoot a fine stream, not more than a millimeter in diameter, with such force as to carry it at least 2 inches from the end of the siphon before the eggs separated into a fine spray, like a jet of smoke, which held together for a time and then spread out in a cloud. This stream ended with the expulsion of stringy chunks of eggs and yellow tissue. Another quahaug shot a continuous jet of spawn for forty-four seconds. The amount of spawn extruded at any one

time was variable. The quahaugs under observation in the laboratory showed a tendency to throw their spawn little by little, although there is reason to believe that in nature it may be possible to discharge all the season's spawn at once. In the laboratory the same lots spawned three different times during the season, indicating that the quahaug is similar in this respect to the scallop.

Methods of Work. — The spawning was followed during 1909 and 1910 by keeping various sizes in tanks freely supplied with running salt water, where they could be under continual observation. For this purpose different grades of quahaugs, as "sharps," "blunts," "mediums" and "little necks," were placed in small lots in different compartments, some in sand, their natural environment, others merely in the water. (A complete description is given under "Methods of Work in Hatching.")

The Spawning Season. — The usual methods of microscopical examination, larval counts by means of the plankton net and records of the appearance of the set were used to determine the spawning season. Results also were obtained from the spawning under artificial conditions in the laboratory aquaria in 1909 and 1910.

From observation of the set, and from the size of the small quahaugs in the fall, it at first appeared that the spawning season was later than with the scallop and oyster. Investigation proved that the spawning season practically corresponds in Massachusetts waters with that of the scallop, *i.e.,* from the middle of June to the middle of August, the small size of the young quahaugs being due to slower growth. This is natural, as the quahaug, like the scallop, is essentially a southern or warm-water form, and its habits are directly influenced by temperature. Quahaugs in the Wellfleet laboratory extruded spawn in 1909 between June 23 and July 13; in 1910 as late as July 29, which further narrows the spawning limits. In the 1909 case it must be remembered that this occurred in one year, in one locality, with certain quahaugs and under possibly unnatural conditions; all of which are variable factors in the determination of the spawning season. One fact was definitely settled. The season lasts but twenty days, or less than a month, for any special batch of quahaugs; but for Massachusetts waters in general nearly two months are consumed, the greater part of the spawning, however, taking place during the last of June and the first part of July.

Temperature and Spawning. — Temperature has great influence over the distribution of all marine animals. It affects mollusks in three important ways; (1) their growth, by regulating the food supply; (2) their distribution, according to the environment; and (3) their development, as determined by spawning, early life history, etc. The time of spawning is so regulated by nature that it takes place when conditions, chiefly temperature, are favorable for the development of the unprotected embryo, which is extremely susceptible to all adversities.

Thus, spawning does not take place until the water has attained a warmth suitable for the development of the offspring. For this reason, the spawning of the quahaug in the southern waters takes place earlier than on our coast, as the requisite temperature has been reached sooner. Whether or not northern quahaugs, by the process of selection, require as warm water for the development of their offspring, and consequently spawn at a lower temperature than the southern forms, is unknown, and can be determined only by a series of observations along the Atlantic coast.

During the spawning experiments at the Wellfleet laboratory, in 1909, the following notes were made: "The first lot of spawn was given off June 23 to 26, during a sudden rise in temperature following a period of extremely cold weather for that season. The temperature of the air in the laboratory between June 23 and 26 during the day averaged from 78° to 80° F., while the water in the aquaria remained at a uniform temperature of 76° F., corresponding with the temperature of the water at the part of the harbor where the laboratory was located. On July 13 spawning again took place, the water attaining a temperature of 77° F., during a warm spell in which the laboratory temperature was 80° F. Between June 26 and July 13 no spawning was observed. It is interesting to note that the water between these dates was only moderately warm, averaging 71° F., and that spawning occurred simultaneously with a rise in temperature of the water, in each case reaching about 76°, which appears to be the 'spawning temperature' for Wellfleet, although in other localities it may be different."

In the light of these experiments the act of spawning during the summer may be likened to the operation of an automatic thermostat, which, when a certain temperature is reached, allows the escape of the contents held under pressure in the distended sexual organs. All the writer's observations tend to prove that temperature is the controlling factor in the spawning of the quahaug, and that the variations, either for different years or in different localities, whether on the north or south side of Cape Cod, in Buzzard's Bay or in the States south of Massachusetts, are primarily due to differences in temperature.

Age and Spawning. — The average quahaug is capable of spawning when two years old, its third summer, as sexual products can be found at that age. The size of the average two-year-old quahaug is between 1¼ and 1½ inches. It is well to realize that size, not age, is of importance in considering sexual maturity, and that a rapidly growing mollusk reaches reproductive activity sooner than a slowly growing specimen. Observations at Wellfleet in 1909 indicate that the quahaug is of little value as a "spawner" until it has attained a size of 2½ inches. In the spawning tanks the quahaugs were separated into small lots, according to size. Practically uniform conditions existed as regards flow of water, temperature, etc. The large (3 to 3¾ inches) and

the small "sharps" ($2\frac{1}{2}$ to 3 inches) were the only quahaugs to spawn. The "little necks" (under $2\frac{1}{2}$ inches) and the "blunts" (old quahaugs) did not throw any eggs or spermatozoa. This fact, if universally true, has an important commercial bearing on the capture of "blunts," as it would tend to show the fallacy of reserving the old "blunts" for "spawners." Before definite conclusions can be drawn frequent tests should be made to verify this observation. Under the conditions in the Wellfleet laboratory the distinction in size, class and age are sharply marked at three different intervals, quahaugs of the same sizes being the only ones to spawn. If the above observations hold generally true, it means that the quahaug has a period of sexual maturity only during middle life. On the other hand, it is a fact that sexual products are found in varying abundance in both "little necks" and "blunts," when the sexual organs are opened, but no proof that they are discharged can be given.

Two peculiarities which may be mere chance were shown by the spawning in the laboratory tanks.

(1) The spawning occurred at night on June 23, 24, 26 and July 13, 1909. No spawning during the daytime was observed until July 29, 1910, when the quahaugs spawned at 5 P.M. The spawning on June 23 and 24 occurred toward morning, while on June 26 and July 13 it took place in the first part of the night; on July 13 beginning at 8 P.M. Although it is probably the result of coincidence that almost all the spawning took place at night, it is barely possible that the quahaug, buried under the sand in the deep water, is not influenced, as the scallop, by sunlight, and that darkness is a factor in natural spawning.

(2) The quahaugs in the spawning tanks were divided into two classes: (*a*) those buried naturally in sand; (*b*) those lying on the bottom of the tank without sand. The second class alone furnished the spawn. Possibly their unusual position and environment made them more susceptible to changes in temperature, and therefore more responsive.

Natural Fecundation. — By the act of spawning the parent quahaug completes its duty to its offspring. But a new individual does not begin even to exist, and no development can take place until a union of the egg and spermatozoön takes place. The reason for the vast number of eggs is now disclosed. The chances of union are rendered more and more uncertain as the swift tides bear away the eggs and spermatozoa. No one can answer definitely what per cent. of the eggs are fertilized in nature, as conditions are constantly varying and fecundation depends almost wholly on chance. It is no wonder that the quahaug needs many millions of eggs, unprotected as they are, since they have to pass through a series of adverse conditions, the first of which is the element of chance in the union of egg and spermatozoön.

Between the egg and the spermatozoön is an attraction which scien-

tists tell us is of a chemical nature, and the minute spermatozoön is drawn irresistibly toward the egg, its final goal. How far this attraction zone extends through the water is not known, but under the microscope eggs can be observed fairly covered by a circle of spermatozoa, as if held there by some centripetal force. But one of these can gain an entrance, as after the body of the spermatozoön has entered the egg to fuse with its nucleus (germinative part) an impenetrable membrane is formed around the egg, shutting out the others. This fusion of the male and female pronucleus gives life to the young quahaug, which now starts through the series of changes described under the heading "Embryology."

All through its early existence, until it is large enough to settle into the sand, the young embryo is subject to continual danger on all sides. Under natural conditions, if but one out of the millions of eggs laid by a single quahaug reaches maturity, it is sufficient to perpetuate the species. The young embryo is thus forced to lead a continual struggle for existence, with but meager chance of survival. If, favored by chance, the union of the egg and spermatozoön takes place, the new individual is from six to twelve days at the mercy of the natural elements. Sudden changes in temperature or in the salinity of the water, such as cold rains, diminish the number of larvæ; the waves and tides wash many ashore; polluted waters may destroy; all manner of sea animals devour them as food; and, finally, the greater part of the remainder fall on poor ground, where they soon perish. The few that fall on good ground are still subject to the attacks of predaceous animals until they attain a sufficient size to resist those enemies.

Hatching.

Although the young quahaugs, from the time of byssal attachment, had been studied since 1906 in the laboratory, successful fertilization was not achieved until 1909, when several lots of embryos were developed in the spawning tanks. This occasion furnished an opportunity to study the embryology and complete the work on the early life history.

The essential object in this work was to find, if possible, a method of artificial hatching which would make possible the raising of seed quahaugs on a commercial scale. The question of seed is of the greatest importance to the quahaug culturist, as the natural beds cannot, as in the case of the clam, furnish a sufficient quantity for an extensive industry. The results of the experimental work in this direction so far have been somewhat discouraging. Two methods of obtaining seed seem possible: (1) the catching of the set in spat boxes in a manner parallel to the catching of oyster seed; the work on this point will be discussed under the subject of "Spat Collecting," which has met with more or less success; (2) the artificial rearing of the quahaug from the egg through the larval stages to a size suitable for planting. By pro-

tecting the helpless larva from its enemies during the most critical period of its life, it may be possible to reduce the great infant mortality, and raise thousands artificially to nature's one. So far we have been able to raise only a few quahaugs to the veliger (shell) stage, the majority perishing for various reasons, chief among which seems to be the lack of food and space. Our experiments have been so designed that if successful on a small scale they could readily be enlarged to meet the requirements of a business enterprise. The work is discouraging from a commercial standpoint from the fact that the chief cause of failure is due to the crowding of the larvæ, whereas to give the young quahaugs a sufficient amount of space would so materially increase the expense of production as to prohibit hatching. However, there are many things to encourage continuation of experiments along this line with the hope of ultimate success.

At the present time it would seem that the liberation in large numbers of larvæ one day old would undoubtedly be of benefit. This could easily be done, as the embryos do not die rapidly, when confined, until the second day. Our experiments have shown that a small number can be raised in the laboratory, enough for the study of the early life history, but that when large numbers are tried the result is unsatisfactory.

Methods of Work in Hatching. — Attempts were first made to fertilize the eggs by abstracting the spawn from male and female quahaugs by artificial cutting, and mixing these in the water. No satisfactory results were obtained by this method, as the eggs would not develop normally. It was finally decided to keep adult quahaugs in tanks supplied by running salt water, and to remove the spawn to special rearing tanks as soon as it appeared.

No facilities for such work were available until the summer of 1909, when a small one-horse power gasoline engine and pump were installed at the Wellfleet laboratory, which is situated on a wharf over the water. At high tide water could be pumped to a large wooden tank at the top of the building, which served as a reservoir. From this tank water was conducted by a large pipe to different parts of the laboratory, where it was supplied to the hatching tanks by rubber hose.

For hatching purposes we used wooden tubs, made of large hogsheads cut in two in the middle, through which passed a continuous stream of water. In order that the flow of water might be maintained without loss of larvæ, the water was drained off through sand filters, fitted so that they could be readily cleaned. This arrangement was accomplished by fitting into the bottom of the tub several short pieces of 3-inch galvanized iron piping in a vertical position. Sand was held in the pipes by wire netting on the bottom and could be removed when desired. For the purpose of aëration the salt water was forced in fine streams into the tanks, keeping the young larvæ

under uniform conditions as regarded temperature, food supply and flow of water.

At the beginning of the spawning season the quahaugs were kept in ordinary tanks. When spawn was discharged into the water it was transferred to the special tubs previously described, and efforts were made to rear the embryos under what seemed to all purposes natural conditions. Large glass aquaria and glass hatching jars were also utilized, the eggs in the latter being constantly kept in slow motion by means of a double inflow of water, one on the bottom furnishing the circulation, the other on the top aërating the water. All sorts of combinations, such as varying the amount of spawn, the rate of flow, the kind of jars, and selecting the more active larvæ by siphoning, were tried in vain, as the quahaug embryos perished in great numbers, only a few reaching the veliger stage.

EMBRYOLOGY.

The embryology of practically all the *Lamellibranchiata* is strikingly similar, the eggs passing through identically the same stages and differing but little in appearance. This similarity holds true until after the formation of the embryonic shell. During the first part of the veliger (embryonic shell) stage the predominating type of a straight-hinged veliger holds true; and it is only in the last part of this period that differentiation in structure and form between species can be noticed. In the report on the scallop the embryology has been described in detail, and in the following pages, owing to the great similarity of the quahaug and scallop larvæ, only a brief description of the general features will be given, emphasis being placed on the points of difference. For a more complete description the reader is referred to the life history of the scallop, published in a previous report.

The first distinction has been already mentioned, the gelatinous case which surrounds the quahaug egg, whereas the scallop egg is naked. The majority of eggs remain within this covering until they become ciliated embryos, when by the rotary action of the cilia they break from its folds. It was a frequent occurrence to observe through the microscope embryos rapidly revolving within the cases.

Polar Cells. — About twenty-five minutes after the egg is laid, two clear transparent bodies, apparently containing no yolk granules, are given off at the flattened animal pole (Fig. 3). The first body by its appearance clearly demonstrates the presence of a membrane about the egg, as it is formed beneath the membrane, which forms part of the adhering strands for the polar cells.

Yolk Lobe. — The appearance of the polar bodies is followed by the formation of a poorly developed yolk lobe (Fig. 3), by no means as conspicuous as in the case of the scallop. No constriction, such as is found with the scallop, is observed with the quahaug egg; but the

nutritive material is confined to one end, which later becomes the large yolk cell (Fig. 4). Just previous to the first segmentation the egg elongates into a pear-like body, the yolk lobe constituting the broad end. The elongation takes place in a direction horizontal to the polar cells and not vertical, as with the scallop.

Cleavage. — The quahaug egg develops by the same process of unequal cell division as the scallop, although the time and form of the divisions are different. The difference in time is probably unimportant, as the warmth of the water has a great deal to do with the rapidity of development in mollusk larvæ. The first cleavage (Fig. 5) is noticed thirty-five minutes after fertilization, and at the end of fifty minutes the majority of the eggs are in the 2-cell stage. The actual time from the beginning to the completion of the first cleavage for individual eggs is about three minutes. The average time for the completion of each cleavage after fertilization for the majority of the eggs was as follows: 4 cells (Fig. 10), one hundred and ten minutes; 8 cells (Fig. 11), one hundred and forty-five minutes; 16 cells (Fig. 13), one hundred and eighty-five minutes; 32 cells (Fig. 14), two hundred minutes.

The principal difference between the cleavage of the quahaug and the scallop egg is found during the first segmentation, and is chiefly due to the elongation in opposite directions. In both cases the first division gives 2 cells, a large and a small; with the scallop the larger cell has an elongated form, due to the construction of the yolk lobe, while with the quahaug both cells are spherical.

The egg passes through the 16, 32, 64, etc., celled stages, until the primitive ovum has become a compact mass of small cells (Fig. 12) surrounding a group of large cells, containing the nutritive yolk. This is the blastula stage of the embryo, which soon becomes a true gastrula by an invagination which forms the primitive digestive tract. About the age of ten hours the surface cells acquire minute hair-like processes (Fig. 15) called cilia, which enable the animal to move. Up to this period the egg has developed inside the transparent case, but the lashing of the cilia soon tears apart the protective covering, and the animal escapes, as a swimming embyro, into the water.

Trochosphere Larvæ. — By the time the embryo is able to break forth from its case the random revolutions of its early ciliated stage have changed, and a new larva, more elongated in form, swims through the water with a definite spiral movement, rotating voluntarily around its longitudinal axis in either direction. The new type of embryo is called a trochosphere (Fig. 16), and reaches that stage at the age of twelve to fourteen hours. It is differentiated from the ciliated gastrula by having an elongated or top-like body; by having the cilia confined to the blunt anterior end; the formation of a primitive mouth; and the appearance of a shell gland opposite the mouth. The trochosphere stage of the quahaug and the scallop are identical in regard to (1)

form of animal; (2) mouth; (3) shell gland; (4) methods of swimming. The only difference lies in the flagellum, or whip-like feeler, formed in the scallop larvæ by the elongation of certain cilia on the anterior end, but probably absent in the quahaug.

In the course of the next twenty-four hours a thin transparent shell (Fig. 17) creeps slowly over the animal, until it completely envelops the soft parts. During this period the animal can be observed swimming through the water with its organs partly covered by two thin valves. The shell is formed by the secretion from the shell gland, which becomes calcified at two points, forming the two valves. With the spreading of the shell various changes of more or less importance, both in the anatomy and habits of the young quahaug, have taken place, giving rise to a period in its development known as the veliger stage, perhaps the most critical and important period of its existence.

The Veliger. — The early veliger (Fig. 18), formed about thirty-six hours after fertilization, is a different appearing animal than the swimming larva of the early stages. When first formed it has a transparent shell with a straight hinge line, which is nearly always held open at an angle of 45°, whether the quahaug is resting on the bottom or in the act of swimming. The animal at this time is but little larger than the trochosphere larva, the empty space between the soft body of the animal and the shell constituting the only gain in size. The ciliated velum has no flagellum, the stomach is prominent, two adductor muscles are present, and teeth are apparently present on the hinge line. The animal swims by means of a velum which is not extruded from the shell. This is the description of an undeveloped quahaug veliger, which has not as yet attained full size, and has not become proficient in the art of swimming with its velum. In the course of a few hours it will have reached the normal size, and will have taken on the attributes of a true veliger.

The straight-hinged quahaug veliger, except for the absence of a flagellum, is similar in every way to the young scallop of this stage. In fact, the majority of lamellibranchs, except *Anomia* and a few others, pass through the period of the early veliger practically identical in form and habits, so much so that it is impossible to differentiate between species. The first traces of individuality are found in the late veliger, in which each species develops a shell peculiar to itself. For this reason the reader is referred, for a detailed description of the early veliger stage, to the report on the scallop (*Pecten irradians*), as only a summarized account is here given.

The veliger stage may aptly be compared to childhood, placed as it is between embryonic development and the attachment stage or youth. Not until this point in its life does any important increase in size occur. This period is divided into two parts, which are styled, for want of a better title, (1) the early and (2) the late veliger, as several anatomical changes differentiate the two. The veliger derives its name from the

peculiar swimming organ or *velum,* which during the first part of this period is one of the most important organs of the animal. With the development of the foot, which takes place toward the last part of the veliger stage, the velum gradually disappears, while the foot, for a brief period, performs its work. The duration of the veliger period depends largely on the temperature of the water, ranging from six to twelve days, during which the veligers can be taken in numbers in the water by means of the plankton net. When swimming in the aquarium they are sensitive to a sudden jar which causes them to pull in the extended velum and settle to the bottom. This circumstance makes it possible to separate the veligers from other plankton forms. The act of swimming is accomplished by the extension of the velum or ciliated pad, the lashing of the cilia propelling the animal in any direction. The entire veliger stage is passed as a swimming larva in the water, occasionally settling to the bottom, where it runs the risk of destruction. It is only brought to an end by the increasing size of the animal, the loss of the swimming function of the foot, and the acquirement of alternate powers of attachment and crawling.

The chief characteristics of the early veliger are: (1) an equivalvular shell with a straight hinge line; (2) a velum or ciliated swimming organ; (3) a primitive mouth lined with cilia, leading into a cavity in the center of the body, the stomach, and an abbreviated intestine with posterior anal opening; (4) an inconspicuous mantle; (5) two adductor muscles. The late veliger is characterized by (1) a shell marked by prominent umbones, directed posteriorly; (2) a well-developed foot, with byssal gland, which has taken the place of a degenerate velum; (3) a more complex digestive tract, with palps and coiled intestine; (4) a conspicuous mantle; (5) two adductor muscles and several primitive gill bars.

The change in the transition between these two forms is quite pronounced as regards: —

(1) *Shell.* — The straight hinge line of the common ancestral form gives way to one of slight curvature by the bulging of the valves to form the umbones. Both valves are of equal curvature, and the embryonic shell has a homogeneous texture which differentiates it from the succeeding growths.

(2) *The Velum.* — The swimming organ, situated within the anterior part of the shell, consists of an elliptical pad, with a border of lashing cilia, capable of extension and contraction, whereby it can be thrust out of the shell or withdrawn quickly by means of muscle fibers attached near the hinge. When contracted the ciliated edges fold inward. The velum is a modification of the anterior ciliated portion of the trochosphere larva. During the middle and last part of the veliger period a degeneration of the velum, with a simultaneous development of the foot, takes place. The growth of a muscular foot seems gradually to obliterate the velum, which can be seen in different stages of

degeneration, the foot with ciliated tip finally assuming the swimming function of the velum.

(3) *Gills.* — Several ciliated V-shaped filaments, capable of extension and contraction, arise on each side of the foot, and eventually become the complicated gills of the quahaug. A thin mantle, closely lining the sides of the shell, similar to the mantle of the adult, is noticeable, while the digestive tract has enlarged in size and length, the straight intestine becoming coiled.

At the beginning of the veliger period we find an animal anatomically equipped to lead a free-swimming life in the water, as is evidenced by its size, shape, lightness of shell and large swimming organ. At the end of this state we find the animal on the verge of another great change. Its free-swimming days are over, and anatomical changes have taken place which fit it to enter upon a new existence, that of youth. The ciliated swimming organ has been replaced by a long muscular foot, which at first enables the animal to swim through the water, but soon loses that power. The shell has changed in size, form and weight, while the soft parts have enlarged to such an extent that further shell growth of a more substantial nature is required. In brief, its free-swimming existence is ended, and, following the invisible law of nature, the structure of the animal has become altered, in preparation for a change of life.

The Attachment Stage.

The attachment of the quahaug marks the end of its embryology and the beginning of its real life under practically the same conditions which surround the adult. The change is accomplished by the development in the foot of a byssal gland which secretes a fine, tough thread, anchoring the animal to any object, particularly sand grains. The method of attachment is described in detail under "The Habits." There is some reason to believe that a crawling stage intervenes between the free-swimming and the attachment periods. If so, it is of slight duration, as the functions of crawling and attachment are supplementary, the welfare of the young quahaug depending both on its resting and its migratory powers. At all events, the time of attachment marks the appearance of a new growth, comparable to the dissoconch shell of the scallop as opposed to the prodissoconch (embryonic shell), which forms the true shell of the adult.

From this time on the changes in anatomy and habits are very similar in the quahaug and the soft clam (*Mya arenaria*), as the environment of both is the same. The habits of the young quahaug are described later, and only the changes in structure will be given here. Specimens for study were obtained from spat collectors, in the form of boxes, which were lowered from a raft in the Powder Hole, Chatham, Mass.

The Shell. — The new growth is sharply separated from the embryonic shell by a definite growth line, and is distinguished by different shell formation, as regards texture, color and lines of growth. The embryonic shell has a smooth homogeneous structure, with fine concentric lines of growth, whereas the new growth is coarser, whiter and characterized by concentric ridges occurring at definite intervals. The color is evidently due to the greater amount of lime salts. The ridges (Fig. 28) are especially prominent in rapidly growing quahaugs less than 1 inch in size, and can be observed on well-preserved adult specimens, where the umbones have not worn away. They reach their maximum size when the quahaug is about ¾ of an inch in length, varying greatly in prominence on the same and different specimens. In quahaugs 1 millimeter in size as many as twelve distinct ridges could be found. No explanation for these prominent lines can be given. In quahaugs ¾ of an inch in size they appear at the rate of two to three a month during the summer, apparently at regular intervals, as the amount of space between ridges seems to depend upon the rapidity of growth. These ridges differentiate the very early stages from *Mya arenaria,* which at first has a round form, different from the elongated adult. Both valves are equal and have prominent umbones, back of which appear faint lunules, the heart-shaped structure so well marked on the adult quahaug. Unlike the young scallop, no byssal notch is present.

The Soft Parts. — At the beginning of the attachment stage the animal has all the organs characteristic of the adult in miniature form. The visceral mass and sexual organs are not conspicuous, the foot is more mobile and relatively larger than the plow-shaped structure in the adult, the byssal gland, absent in the adult, is a conspicuous appendage of the foot, and the other organs, differing in size, position and development, are but rudimentary. As the quahaug increases in size these organs take on adult characteristics, and by the end of the attachment period (size, 9 millimeters), they conform in practically every detail with the adult.

(1) *The Mantle.* — The mantle appears larger than that of *Mya* (soft clam), and is pressed into a series of folds at the free margin, which gives the appearance of a number of large knobs or tufts. In the young the margin is ciliated and sensitive to touch, but in form it differs little from the adult, which apparently has maintained the primitive lamellibranch mantle.

(2) *The Siphon.* — The mantle edges at the posterior end of the young quahaug, almost at the beginning of the attachment stage, are modified to form the excurrent and incurrent siphons, which constitute the "neck." The siphon is very similar to the same structure in the clam. The excurrent part has the same filmy telescopic attachment (Fig. 29) which draws in and out with a folding motion. When a stream of water is shot out, the transparent tube is cautiously unfolded and held as a hose to direct the flow. The average time of

expansion was found to be four seconds, the time of contraction varying from two to eleven seconds. In crawling, there appears to be a certain degree of unison between the outflow of water and action of the foot which may assist the progress. This excurrent attachment gradually disappears as the quahaug grows older, although in one-half or three-quarter inch quahaugs a remnant can be observed on the edge of the excurrent siphon. The edges of the siphons are lined with tentacles, as this is a most important sensory part of the mantle, the incurrent siphon having about three times as many as the excurrent. In a 1-millimeter quahaug twelve tentacles were counted on the incurrent and four on the excurrent siphon, a greater number than on a clam of the same size. These large tentacles are probably of greater use as sense organs to the young quahaug than to the old. Very little color is found on the mantle and siphon, except on the tentacles, which sometimes are strongly pigmented.

(3) *The Foot.* — The early foot is a muscular body, capable of an extension equal to two-thirds the length of the shell. At the tip the cilia are somewhat longer, possibly aiding in the strong grip which is exerted at this point, enabling the quahaug to crawl along a surface. On each side of the foot is a circular otocyst or balancing organ. On the ventral side of the foot projects a papilla with a deep cleft, the byssal gland. It is more prominent than the byssal gland of the scallop.

(4) *The Gills.* — The few simple filaments of the veliger stage increase in number, forming the inner gill, while new buds repeat the same process to form the outer. As the gills enlarge they become more complicated, taking on adult characteristics.

(5) *The Muscles.* — The two adductor muscles remain in the same position, enlarging in proportion to the amount of increased work.

(6) *The Reproductive Organs.* — The visceral mass is formed above the foot, and is not visible until toward the last of the attachment stage, when the foot becomes relatively smaller and less motile. In this body are the ovaries or testes, according to the sex of the quahaug.

(7) *The Digestive Tract.* — The liver, arising by two ducts from the side of the stomach, enlarges rapidly and takes on a dark brown color. The intestine increases in length by forming tortuous coils in the visceral mass, and after piercing the ventricle of the heart, terminates behind the anterior adductor muscle.

THE HABITS.

A study of the habits of any animal frequently leads to the discovery of facts which can be utilized for practical purposes. In the case of the quahaug at least three habits are directly related to artificial cultivation: (1) the method of attachment, which furnishes possibilities for spat collecting; (2) the non-migratory life, which makes planting

possible without enclosures; (3) the method of feeding, which suggests the probability of increasing the rate of growth, fattening and even producing special flavors. In addition, notes upon other topics are presented, such as enemies and environment, which do not properly come under the definition of habits, but to a greater or less extent influence the life of the quahaug. As far as possible these subjects have been arranged in accordance with the development of the animal.

Attachment.

Attachment takes place at the end of the veliger or free-swimming stage, when the young quahaug fixes itself to various objects by means of a horny thread called the byssus (Fig. 28), secreted from a gland in the foot. The objects of attachment are sand grains, shells, boxes, eelgrass, sea lettuce, etc. The period of fixation marks the change from an active swimming existence to a more sedentary mode of life. The gland which secretes the byssus in most lamellibranchs is situated in the ventral side of the foot, and varies in size and appearance. Lining the sides of this gland, which has the appearance of a pore, are a number of little cells which furnish a mucus-like secretion which, when coming in contact with water, immediately hardens, forming tough threads of conchiolin, a complex chemical substance of horny nature.

The byssus in the different lamellibranchs has a variety of forms. In some it consists of a number of soft glossy threads bundled together, as in the young of *Pecten*, the scallop; in the mussel (*Mytilus*), where it is an important organ of the adult, there is a thick bundle of hair-like threads with disks at the ends which are attached to the object of support; *Anomia*, the silver or jingle shell, has a calcareous byssus which projects through the lower shell and strongly attaches to the animal; and in the young of the soft clam (*Mya arenaria*) it consists of a single translucent thread with several branches. In the mussel the byssus in the adult has no connection with the foot, but is situated behind it, forming an almost permanent attachment for the support of that mollusk. Nevertheless, the mussel is reported to be able to move along slowly by the formation of new threads and the destruction of the old strands (Williamson, 13). Certain lamellibranchs seem to have lost the byssus through disuse, some apparently never possessing this organ at any stage of their development. Another class retains the byssus for certain periods, *e.g.*, the clam, which makes use of the power of attachment until it reaches a size capable of burrowing deeply in the sand, and the scallop, which throughout its life retains the power of byssal fixation, but does not use it to any extent after the first year.

The adult quahaug possesses no byssus as it has no need for that organ. For a long time there has been considerable question as to whether the quahaug in its early life possessed such an organ. Ryder (12) in 1880 found that the young of the soft clam were attached by a single branching thread to seaweed and sea lettuce. This fact was

clearly demonstrated by Kellogg (4) in his report on the "Life History of the Common Clam," in which he gave some excellent drawings of the byssal attachment, and proved that the attachment stage was a necessary part of the life of the young *Mya*. At this time it was surmised that the quahaug likewise had a byssus during the early part of its existence. Proof was first obtained September, 1906, when it was the good fortune of this department to record the attachment of young quahaugs (*Venus mercenaria*) in the spat boxes at Monomoy Point.

The byssus of the quahaug is in appearance so similar to the same organ in the soft clam that if it were detached a person could not tell the two apart. In use, structure and formation the two threads are exactly the same, so that, in describing the attachment of the quahaug, use is made of facts recorded for the clam by Kellogg (4). The byssus consists of a single thread, normally from 1/4 to 1/2 an inch in length, but so elastic that it can be stretched to a length of 1 1/2 inches without breaking. Several branches, usually not more than two or three, extend from the lower part of the thread, and at their distal ends divide into strands like the delta of a river, which spread out on the foreign object, fastening themselves apparently by little suckers or stickers. The thread is of uniform thickness, except at its distal end, where it is slightly finer. Under the microscope the thread has a translucent glossy appearance, similar to strands of prepared gelatine.

The quahaug first attaches itself at the close of the veliger or free-swimming stage, when a prominent byssal gland is formed on the ventral side of the foot. The quahaug retains the power of attachment until it has attained a size capable of burrowing firmly in the sand. The largest quahaug observed with a byssus measured 9 millimeters, and was found in a spat box at Monomoy Point, Oct. 13, 1906.

Many observations on the byssal attachment of the quahaug were made at Monomoy Point, where the quahaugs were obtained in spat boxes suspended from a raft. The attached quahaugs were observed here during August and September in 1906 and 1907, and in 1908 as early as July 24. The majority of these quahaugs were buried in the sand and attached to the sand grains by the byssal threads. Occasionally a quahaug was found attached to the sides of the box out of the sand. At Wellfleet small quahaugs were found attached to the shells put down for the capture of oyster spat, and many times quahaugs were raked up adhering to shells and other material. Likewise young quahaugs were frequently observed to attach themselves to the glass dishes in which they were kept for study in the laboratory. These observations show that, while the majority settle in the sand, the quahaug can "set" on objects such as shells, boxes, eelgrass and sea lettuce, and in the latter cases can be carried such distances as described for the soft clam by Kellogg (4). Thus, the quahaug is comparable with the clam, which "sets" both out of and in the sand. Practically all the quahaugs attached out of the sand were between

2 and 3 millimeters in size, no large ones being observed, which indicates that the quahaug "sets" but temporarily out of the sand.

The time of spinning a byssus is comparatively short. No direct observations have been made on this point; but it has been known to break the old and form a new one within a few hours. It is doubtless a much shorter time, as the young scallop has been seen to spin a similar byssus in three minutes.

The process of attachment has not been studied. In general the embryo, swimming with its foot, strikes a surface, presumably catches hold with its foot, and, after crawling to a suitable place, spins its byssus. In other cases it strikes some object, and closing the shell drops to the ground, where it passes through the same process, only attaching itself to the sand grains. The young quahaug has the power to cast off the byssal thread at will and spin another. The thread separates from the animal at the byssal gland and remains clinging to the object to which it is attached. This is probably of constant occurrence, especially with the smaller quahaugs, as they are quite active at this stage, and in traveling from one resting place to another must repeatedly break the thread and quickly spin another. At this period the animal alternately leads a traveling and a sedentary existence.

Unquestionably the byssus is of importance to the young quahaug, as otherwise this organ would have degenerated from disuse. Primarily the function is protective, as it enables the animal, though of small size, to remain in the sand, and prevents its being washed from its shallow burrow. Again, in the earlier stages the attachment to various objects keeps the young quahaug from being smothered in silt, or from being washed ashore to its destruction. Attachment is needed only until the quahaug obtains sufficient size to protect itself by burrowing more deeply in the sand. The slender thread though small is uunusually strong, resisting a considerable pull before it parts, and can be considered as the anchor cable which moors the quahaug.

The "Set."

The time of "set" varies, as it depends upon the spawning season. Usually the young quahaugs are noticed slightly later than the young scallops. At Monomoy Point, in the raft spat boxes, small quahaugs have been observed by the naked eye as early as July 24, in 1908, while in other years they have not been recorded until the second week in August. The "set" is not abundant, as is the case with the clam, and no quantities of young quahaugs comparable to the heavy "sets" of small clams are found. The fact that the "set" is usually below the low-water mark perhaps explains the failure to find thickly "set" areas, as many beds escape the attention of the quahauger. As it is, but few localities of heavy "set" are known. At the present time the Acushnet River furnishes the greater part

of the small quahaugs, though in some years the Mill Pond in Chatham; Tuckernuck Island, Nantucket; Katama Bay, Edgartown, have also contributed considerably. The Katama Bay region maintains the steadiest supply, owing to the protection of the quahaugs under 1½ inches by the town of Edgartown, while in the case of Chatham and Tuckernuck Island the supply is very erratic. The beds have been depleted, have remained barren for a time and have again received other heavy "sets."

When the first attachment has been made, either to shells or sea lettuce, there is a later migration to the sand, but usually the "set" comes directly on the soil. The nature of the bottom largely determines the future welfare of the "set," which will soon perish if the ground is unsuitable. An excess of silt, slimy mud, shifting sand, proves unsuitable for the existence of the young animal, showing that only portions of the sea bottom are favorable for the existence of the young quahaug.

The same causes which influence the "set" of the soft clam to a large extent determine the abundance of young quahaugs in any locality. Its nature depends largely upon the location in respect to the shores and current, and definite combinations are necessary. As with the soft clam, it has been noticed that the "set" often occurs in an eddy, or on the sides of a swift current. In the Mill Pond at Chatham the "set" is found on the bar reaching part way across the entrance to the upper part, over which the tide sweeps back and forth. A similar case is found at the tip of Jeremy's Point, Wellfleet, and on the gravel bar, over which the tide flows with great speed, large numbers of seed quahaugs can be obtained. In the latter case the bar is exposed at low water during the low running tides.

The quahaug over ½ inch in length is comparatively free from the enemies which attack other shellfish, as its hard shell renders it immune from all except the horse-winkle (*Fulgur caniculatus* and *carica*) and the common cockle (*Lunatia heros* and *duplicata*). Severe winters and other climatic changes affect the quahaug but slightly, except on the exposed flats between the tide lines. So we find in the quahaug an animal which for the greater part of its life is better protected from enemies than the other commercial shellfish. On the other hand, the female quahaug produces the same quantity of eggs as the other shellfish. Therefore, the struggle for existence must be exceptionally severe during its early life or free-swimming period, furnishing a possible explanation for the frequent failure of the quahaug "set."

Spat Collecting.

In the oyster industry the importance of spat collecting became apparent as soon as the natural beds ceased to yield a sufficient amount of seed for planting purposes. In considering quahaug culture the

question naturally arises as to whether there are any artificial means of raising young quahaugs for planting. The importance of having a good supply of seed is apparent. We have previously stated that at present there is no practical method of raising the young quahaug from the egg, owing to its small size and delicate nature. The other possibility is the collection of the quahaug seed from the water by some method of spat collecting similar to that used for the oyster.

When the oyster "sets" at the end of the veliger period it attaches itself by a calcareous secretion to shells and rocks. The quahaug, on the other hand, attaches itself by a single-threaded byssus to sand grains or other clean objects. Attempts were made to catch the quahaug at this stage by spat boxes, — small dry goods boxes, partly filled with sand, — which were suspended from the raft at Monomoy Point. In these boxes quahaugs were obtained at the end of the spawning season in more or less abundance, for the study of the early life history and for the growth experiments. In all probability the young larvæ, when ready to "set," strike the sides of the box and settle in the sand, where they are held in by the sides of the box. Unfortunately, while these boxes proved useful in obtaining quahaugs for experimental purposes, the amount collected was insufficient for commercial purposes. The largest number ever found in one box was 75 per square foot of surface, and the majority of boxes yielded less. To make such a method commercially important it would be necessary to obtain several hundred quahaugs to the square foot of surface. For this reason, unless the essential principles of this method can be applied on a large scale with better success, it is hardly practical to obtain the seed in this way. A better solution would be to develop the places which are naturally suited for the catching of seed by the building of gravel bars, and by artificially directing tidal currents, in other words making nature supply the seed.

Locomotion.

The organ of locomotion for the adult quahaug is the foot, which is described as situated on the ventral surface of the visceral mass in the form of a keel-like projection. Its shape enables the foot to readily enter the sand in the same manner as a plow, so that the animal can turn over, burrow or even crawl through the sand. The foot is composed of comparatively tough muscle fibers, and its action is aided by retractor muscles, anterior and posterior, which are attached to the shell above the fixation of the adductors. As with the soft clam (*Mya arenaria*), the foot is distended by the influx of blood from other parts of the body. The movements of the adult are confined to two forms, (1) burrowing and (2) crawling, the former being the more common.

Burrowing is the act of forcing the shell of the quahaug into the sand below the surface, and is accomplished by the action of the foot. Usually this act is performed when the quahaug lies under the water, but it may be possible for the animal, like the sea clam, to enter the

sand when exposed to the air. The soft clam requires to be covered by water before it can burrow properly. The quahaug, resting on the surface, cautiously extends the muscular foot through the slightly opened valves, working it down among the sand grains until a sufficient purchase is obtained to raise the shell on edge. The shell by a series of jerks is pulled down after the active foot, until the animal is entirely buried beneath the surface, the external openings of the short siphons remaining in view. The length of time depends upon three factors, (1) the size of the quahaug, (2) its activity and (3) the soil. The large quahaugs take longer to burrow, as they are less active, heavier and require more force to enter the sand. The foot is relatively larger in the small quahaugs than in the large, and naturally the young show greater activity in burrowing. Besides age, the activity of the quahaug depends upon the temperature of the water, as below 50° F. they burrow slowly, often lying for long periods on the surface. This is an important fact for the planter, as there is danger in winter planting, owing to the exposure from non-burrowing. The nature of the soil, whether compact or loose, hard or soft, determines to some extent the rapidity of burrowing. When conditions are favorable, burrowing is usually accomplished within a few minutes. Out of 1,500 quahaugs planted at Monomoy Point in sixteen different lots on June 4, 1906, and Oct. 10, 1905, when the water was about 62° and 55°, respectively, 92 per cent. had burrowed within twenty-four hours after planting. The quahaugs were small, less than 41 millimeters, and in good condition. The June beds gave 94 per cent., the October beds 85½ per cent., showing the effect of temperature.

The power of burrowing is necessary for the quahaug in the same way as for the soft clam. Whenever the animal is forced or torn from its burrow by natural or artificial agencies it can again resume its natural position in the soil.

The quahaug also possesses the power of crawling, as it is equipped with all the necessary organs for progress through the soil, but does not make use of this faculty to any great extent. The act of crawling is accomplished in much the same way as the burrowing, which is a modification of the original crawling habits of the young. After burrowing in the soil the animal works the extended foot forward, forming a way for the shell, which is pulled after the foot. The movement is anterior, *i.e.*, the siphonal end of the animal brings up the rear, the end of the shell projecting so that a winding trail is left on the surface of the sand, showing the course of the animal. Crawling is effected by the same conditions which influence burrowing, such as temperature, soil and size of the quahaug, the older animals moving very little, while the young forms are more active. In one instance a blunt quahaug between the tide lines was found to have crawled 7 inches in twenty-four hours. All movements in this bed were in the direction of the retreating tide. While crawling is more often observed between

the tide flats, it also takes place in the natural habitat, below low-water mark. On wet flats the quahaug can possibly crawl without water over it; but most of the crawling is done under the water.

Various writers have referred to the quahaug as wandering between the tide lines, as if the animal were constantly moving from place to place. In reality the quahaug moves but little, and usually at a slow rate, as by force of habit it is a stationary animal. The writer several times has observed its wanderings, as shown by the marks on the tidal flats, but has never found evidence of its traveling any great distance. On the other hand, from general observations and from planted beds which were left for years, he has invariably found that the quahaugs remained in the same localities where placed. Even the smaller, active quahaugs, 3/4 of an inch, which are more prone to crawling, have been observed to remain where planted. Kellogg (2) in 1903 was the first to note that there was practically no migration of the quahaugs in his beds, which he found intact several months after planting. All our growth experiments substantiate Professor Kellogg's observations, as in no case was there any general migration. Therefore, it can be concluded that, while the quahaug has the power of moving, possessing as it does the necessary organs for crawling, it makes use of this habit but little, and when placed on satisfactory bottom will remain within a few feet of its original position. The importance of this fact to planters should not be overlooked, as otherwise the prospective culturist will be afraid that his planted crop may move. Such is not the case, and the culturist need never fear any appreciable loss through migration.

The proofs on which the above conclusion is founded are three: (1) observations on many growth experiments; (2) experiment on movement below low-water mark; (3) experiment on movement between the tide lines.

(1) The facts on this point have already been given. In all the growth experiments the quahaugs were found a year or more later in the immediate vicinity. In no case had there been any marked migration. In several beds, planted between the tide lines at Monomoy Point, which were taken up eleven months after planting, nearly all the quahaugs were found within 3 feet of the original beds. In one bed the quahaugs were of small size, measuring 17 millimeters in length, showing that even the young, active animals were not inclined to wander.

(2) A means of roughly determining the migratory powers of the quahaug was tried at Monomoy Point in 1906. Short stakes, in width and thickness 3 inches by 1 inch, were driven in the coarse sand in the Powder Hole in front of the laboratory, where there were 2 feet of water at low tide. Six quahaugs were placed in order around the stake, 1 at each end, 2 at each side, with the tips of their shells just

touching the wood, so that any movement could be readily determined. Four lots of 6 quahaugs each, measuring 28, 29, 40 and 41 millimeters, were placed in position Sept. 14, 1906, and examined three times, at intervals of three, fourteen and thirty-eight days, respectively, at each examination the quahaugs being left where found, so that the final observation recorded the total movement for the entire period. On the first examination after three days 5 quahaugs out of the 24 had moved from their original position, moving from ½ to 3 inches, on an average of 1 inch. In fourteen days 8 more, 13 in all, had moved, the average distance this time being 1.27 inches, the minimum distance traveled being ½ inch and the maximum 3 inches, while 1 quahaug was missing. After a period of thirty-eight days 4 were reported missing, 5 remained as originally placed and 14 had moved an average of 2.15 inches, with a minimum of ½ inch and a maximum of 6 inches. What became of the 4 missing quahaugs was not determined, and it is a matter of conjecture whether they crawled away or were washed out of their burrows in the sand. The distance covered by the 15 that moved is very slight and unimportant. If the quahaug were naturally a migratory form, as the sea clam, within thirty-eight days all would have traveled away; but considering the fact that 83 per cent. of the number remained within a few inches of their original position, it can be concluded that the quahaug leads practically a sedentary life. No difference was noticed in the movement of the 28-millimeter and the 41-millimeter quahaugs, as the number of large and small which moved were about the same, although the larger quahaugs covered about twice as much distance as the small. A parallel experiment with sea clams (*Mactra solidissima*) was conducted under the same conditions, with the result that all disappeared in the course of a few days after planting.

(3) A similar experiment was tried between the tide lines at Monomoy Point on a sand clam flat. Five stakes were driven in the flat, and quahaugs were planted close to these on Sept. 18, 1906. One month later all but 1 out of 57 quahaugs were found within 6 inches of the posts, showing that, even between the tide lines, the so-called wandering zone, the quahaugs showed no tendency to migrate.

Movement of the Young Quahaugs.

(1) *Swimming.* — The swimming period of the quahaug's life lasts during its embryonic existence, ending soon after the completion of the veliger stage, although the footed larva has for a short period the power of swimming with its muscular foot. The embryo acquires the power of moving through the water at the age of ten hours, when the surface cells are equipped with minute hair-like processes, cilia. The early movements consist of random revolutions of a spiral nature. Two hours later, definite direction is established by the elongation of

the animal, which now swims with a spiral movement, rotating around the longitudinal axis. With the growth of the embryonic shell, about thirty-six hours after fertilization, the animal, now called the veliger, swims by means of the velum, a muscular pad covered with long cilia. The velum has been derived from the anterior ciliated area of the ciliated larva. The animal opens its shell, thrusts out the velum, and is propelled by the action of the cilia in any direction. During the summer spawning months the water is full of these small veligers, which can be taken by a plankton net of silk bolting cloth. When startled, as by a sudden jar, they cease swimming, pull in the velum, close the shell, and settle to the bottom. During the veliger stage occurs the loss of the velum and the appearance of the foot, which takes its place, at first as a swimming, later as a crawling organ. Swimming is accomplished through a kicking movement of the foot, which propels the animal through the water. A similar movement has been seen in adult razor clams, which have been observed to swim through the water for short distances by the kicking with the long foot.

(2) *Crawling.* — With the young quahaug crawling is somewhat different than with the adult, and is similar to the crawling of the young clam. Observations were made on quahaugs from 2 to 3 millimeters in size. At this age the flexible foot is elongate, and more like the blade of a knife than the keel-shaped foot of the adult. Two methods of crawling were observed.

(*a*) *The Forward or Following Movement.* — The forward movement is the common means of crawling, and is similar to the methods observed in the young clam and scallop. It consists of extending the foot and dragging the body after it, in the same manner as the adult quahaug moves through the sand. Fig. 20 shows the foot just appearing from the shell. The mantle and siphon are extended, while the angle between the shell and the foot is acute. This is the beginning of the movement. Fig. 21 shows the foot extended to its full length. It has made a twist so that the bottom part of the ciliated tip can get a firm hold. By straightening out this twist the shell is raised on edge to its natural position when in the sand. The usefulness of this movement is explained by the fact that the quahaug, when exposed, lies flat on the surface of the sand, and that the shell is thus raised on edge, so that it can enter the sand with a cutting edge. The next movement (Fig. 22) is what might be styled a "downward tip," as this action is likewise of use in entering the sand as a wedge. Then quickly follows an upward tip (Fig. 23). By these two tips the quahaug has withdrawn within the shell all but the extremity of the foot, and is now ready for another start. The distance covered is three-fourths the length of the foot. The two tips are caused by the retractor muscles of the foot. In the downward tip the anterior retractor pulls on the anterior portion of the foot, resulting in the downward tip to the anterior portion of the shell, and the second or

upward tip is the result of a similar action of the posterior retractor. A 3-millimeter quahaug was observed to travel at the rate of an inch, over eight times its length, in two minutes, covering about 1/17 of an inch at each movement, the average time of each movement being about seven seconds.

(*b*) *Backward Movement.* — The young quahaugs make use of another method of crawling, though less frequently than the first. This movement resembles a kick, and sends the shell backwards or sidewise. In Fig. 24 the foot is turned under the shell until the tip finds a resting place. Then by a jerky motion the shell is raised from the bottom and hurled to the position of Fig. 25 by a direct backward thrust. The foot is then drawn in and the same performance repeated. Sometimes the shell rests on the same valve, sometimes it is turned over so that on the completion of the movement it rests on the opposite side (Figs. 26 and 27). There is a similarity between the forward and the backward movements as they both depend upon the contraction and the expansion of the foot, but they differ in the application of the force, the first being a pull and the second a thrust. The average of 12 cases observed gave six seconds as the time consumed from start to finish by this movement, as compared with seven seconds for the other. The longest time observed was ten seconds, the shortest, four.

It is interesting to note that while in the case of the scallop a direct relation can be noted between the expulsion of water from the siphonal region and locomotion, in the case of the quahaug such cannot be definitely established. Possibly there may be a slight aid during the forward movement, although the flow of water is not co-ordinated with the contraction of the foot, as with the scallop. In the backward movement there is no assistance whatever.

(3) *Rate of Crawling.* — The following observations were made on the distance traveled by small 2 and 3 millimeter quahaugs. Small round glass dishes, 1⅝ inches in diameter, were partly filled with fine white sand. Two quahaugs 2 and 3 millimeters were put in the center of the dish, which was placed in the aquaria. On examination fifteen minutes later it was found that the 2-millimeter quahaug had traveled 32 millimeters, or sixteen times its own length, *i.e.,* the rate of 5 inches per hour. The first 23 millimeters were through the sand, the last 9 on the surface. On a second examination, one and one-half hours later, the quahaug had only traveled 10 millimeters more, this time under the sand. The 3-millimeter quahaug had not moved at all, remaining in the position originally placed in the sand.

Three other quahaugs, 2 millimeters, 3 millimeters and 3 millimeters in length, respectively, were placed in a dish 3 inches in diameter, filled with white sand. Examined six hours later, they had moved 11 millimeters, 26 millimeters and 100 millimeters, respectively.

Recovery from Injury.

In several cases the shells of the quahaugs have been broken in planting. Unless the break or crack is too large the wound will heal by the formation on the inside of a new layer of shell, the old crack never joining, but merely heing held together by the new growth underneath. It is well for the quahaug culturist to know that slight breaks are not always fatal to the quahaug, and that, in planting, broken ones should not be discarded.

The Feeding Habits.

The food of the quahaug, as of all the lamellibranch mollusks, consists principally of diatoms, — minute plant forms which are found in all waters. These little plants vary greatly in size and shape, often the species of one family but faintly resembling each other. Their chief characteristic is a silicious case, which distinguishes them from other plankton forms. The marine diatomaceæ are somewhat different from the fresh-water forms, but maintain the same general family characteristics. They are abundant throughout the water, although the lighter and smaller forms are most numerous near the surface. These surface species are naturally of less food value than the large, deeper forms. On the various soils which constitute the bottom, the diatoms are constantly reproducing and adding to the supply in the water. It has been found that mud furnishes better breeding places than sand, and that the color of certain surface soils is often due to the kind of diatomaceous growth. An increase in the temperature of the water results in more rapid reproduction. Other minute forms of plankton life are ingested by the quahaug, unless they are too large, in which case, by a complicated mechanism of the ciliary tracts, they are discarded with silt and other foreign material. In this way the quahaug shows a selective power in feeding. Small crustaceans, larvæ of mollusks and crustaceans, protozoa, rotifers, bacteria, etc., constitute a part of the quahaug food, the quantity depending on the location and the season.

The following account is taken from the work of Prof. James L. Kellogg, who has ably described the feeding habits of the quahaug in his report upon " The Feeding Habits and Growth of *Venus mercenaria*." The subject-matter is presented in condensed form, as only the important features are given. From the previous description of the anatomy the reader will remember that just inside the shell lies the mantle, enclosing the body in a fleshy case. Posteriorly the mantle lobes are fused to form two tubes, the incurrent and excurrent siphons, through which a steady stream of water enters and leaves the mantle chamber. Suspended in the mantle chamber, on each side of the visceral mass,

are two conspicuous folds, the inner and outer gills, which play an important part in the collection of the food. On each side of the mouth, which is on the median line behind the anterior adductor muscle, are the palps, which are similar in appearance to the gills and function in conducting food to the mouth.

We have seen that a constant stream of water entered the mantle or branchial chamber. What becomes of it? And what is it that causes the current? All of this water in the mantle chamber streams through the minute openings between the filaments of the gill and enters its interior space. It now rises to the base of the gill, and flows into a tube, the epibranchial chamber, through which it passes backward, leaving the body by the upper or exhalent siphon, which is directly continuous with the epibranchial chambers of the four gills. The currents which we first noticed, then, enter the mantle chamber by the lower siphon, pass into the interiors of the four gills, flow to their upper or attached edges, and are directed backward and out through the upper siphon tubes of the mantle.

The cause of these rapid currents is revealed by a microscopic examination of the rods or filaments of the gills. These are found to be covered on their outer surfaces, which face the water on both sides of the gill, with innumerable short, hair-like structures which project perpendicularly from the surface. These cilia are protrusions of the living protoplasm of the cells which form the walls of the filaments. Each possesses the power of movement, lashing in a definite direction, and recovering the original perpendicular position more slowly. This movement is so rapid that it cannot be seen till nearly stopped by inducing the gradual death of the protoplasm. It is very effective in causing strong currents in the surrounding water.

A microscopic examination, and direct experiment with minute, floating particles, will show that other cilia are present on the filaments than those which cause the water to enter the gills. The diagrammatic figure of the gill does not show why the minute food particles may not be taken into the interior of the gill by the entering stream of water, and finally out of the body through the broad water channels. This is prevented by long cilia arranged in bands, which project out laterally between contiguous filaments in such a way as to *strain* the water which enters the gill, thus preventing all floating matter from entering. These highly specialized cilia tracts of lamellibranch gills I have called the "straining lines." In some forms there is a single line, in others there are two. In some cases the lines are formed by a single row of cells; or a section across the line sometimes reveals several closely crowded cells bearing the greatly elongated straining cilia.

That foreign matter is really excluded as the current of water enters the gill, may be demonstrated by direct experiment on a living gill. Carmine may be ground into a fine powder, and suspended in water without becoming dissolved. If a small amount of this is allowed to fall on the surface of a living gill, it will be seen to lodge there. A wonderful thing now occurs. A myriad of separate minute grains, which may represent the food of the clam, are almost instantly cemented together with a sticky mucus which is secreted by many special gland cells in the filaments, and the whole mass,

impelled by the oscillations of the cilia, begins to move with some velocity toward the lower or free edge of the gill. On this free margin is a groove into which the material collected on the faces of the gill is turned. This groove is also lined by ciliated cells, and the whole mass is swept swiftly forward in it toward the palps. The natural food of the clam, of course, is carried forward in the same way. It is evident that a large proportion of the organisms floating in the water which enters the mantle chamber must come in contact with the sides of the gills, and be carried forward to the mouth folds, to which they may be transferred. . . .

If we now examine the palps with a hand lens, we may notice that their inner surfaces — those nearest to the mouth — are covered by a set of very fine parallel ridges. They are capable of many movements. They may be bent and spirally twisted, lengthened or shortened, and, if their inner faces touch the edges of the gills, any material which is being brought to this region is transferred onto the ridges of the palp. This is accomplished by strong cilia which are developed on the ridges. These same cilia carry the foreign matter on across the ridges, and finally force it into the mouth.

Enemies.

The adult quahaug is well protected from enemies by its hard shell, while the young larva is at the mercy of both the natural enemies and adverse physical conditions, which make its existence most precarious. We can divide the enemies of the quahaug into two classes: (1) the enemies of the young; (2) the enemies of the adult.

Enemies of the Young. — Adverse natural conditions, rather than active enemies, destroy vast numbers of the quahaug larvæ. Up to the time of attachment the young quahaug is at the mercy of tide, wind, changes in temperature, cold rains, etc., which either wash it ashore or kill the delicate embryo by sudden changes. All manner of fish, crustacean and molluscan life feed on the larvæ, even the mother quahaug sucking down her own offspring. The young quahaug must "set" on good ground or perish. In this way nature has regulated the number of eggs in the individual quahaug so that the large number compensates for the great destruction. Even when the quahaug has "set" it is not free from enemies. It becomes the prey of ducks and other water fowl if it happens to settle in shallow water. While no actual instances have come to the notice of the writer of taking quahaugs from the crops of water birds, other small shellfish of a similar nature, although adults, have been found. If these mollusks were eaten, it is possible that the small quahaugs would also be taken. Such mollusks as *Lævicardium mortoni* and young razor clams (*Ensis directris*) have been found in the stomachs of flounders, and naturally small quahaugs could be taken in the same manner by bottom-feeding fish. Instances have been recorded where small quahaugs have perished by washing ashore in storms, showing that even when protected by a shell they are at the mercy of the elements. Starfish, particularly

the young "star," probably prey upon the young form, and it is possible for the oyster drill to attack a small quahaug.

Enemies of the Adult. — The enemies of the adult can be grouped into two classes, — the active and the passive. The active enemies are given in order of their importance: (1) man; (2) the winkle or cockle (*Lunatia duplicata* and *heros*); (3) the conch (*Fulgur caniculatus* and *carica*); (4) the starfish. The passive enemies are those which feed on the same forms as the quahaug, in certain cases depriving it of its sustenance, in others hindering its growth. As such may be renumerated mussels, other shellfish of no economic value, seaweeds, etc.

(1) *Man.* — It is hardly necessary to more than mention man as the greatest enemy to the quahaug, because this report has shown in numerous ways, especially in the historical review of the fishery and the description of the quahaug beds, how man, through excessive digging, has gradually reduced the natural supply. It need scarcely be stated that, unless some method of culture is inaugurated within the next few years, the quahaug industry will become commercially extinct through overfishing by man. Man has overthrown the balances of nature both by ill-advised methods of overfishing and by changes in conditions through the pollution of the streams and waters. Man is and will be the greatest enemy of the quahaug unless he repair the damage already done and assist nature in renewing the supply.

(2) *The Winkle.* — The common bait winkle or cockle (*Lunatia heros* and *duplicata*) attacks the quahaug by perforating its shell in the region of the umbo by means of a rasping tongue armed with sharp teeth. The animal drills a clean countersunk hole from 1 to 6 millimeters in diameter, according to the size of the cockle. While the chief prey of the winkle is the sea clam, it will frequently attack both the quahaug, especially the "little neck," and the soft clam. Owing to the thick shell the quahaug is more immune than the sea clam, as it takes the winkle much longer to pierce the shell and suck out the contents. At Monomoy Point numbers of quahaugs were killed by the winkle in the experimental beds. In nearly every case, although variations have occurred, the perforation was made directly on the projecting umbo or beak of the quahaug. Although the winkle, with the exception of man, is considered the greatest active enemy of the quahaug, it can be readily prevented from injuring the quahaug beds by a little care on the part of the culturist. The cockle never appears on the quahaug grounds in such numbers that it is impossible to gather them, and owing to the high price of these snails for bait, \$3 to \$4 a bushel, it is highly profitable for the quahaug planter to capture them for the market, at the same time preventing damage to his quahaugs.

(3) *The Horse-winkle.* — The extent of the damage caused by this large gasteropod mollusk cannot be determined, and possibly may be

greater than the destruction by the cockle. The oystermen claim that large numbers of oysters and quahaugs are destroyed by the horse-winkle. The method of attack, which has not been studied by the writer, is aptly described by Colton (14), who states that quahaugs are eaten in from seven hours to three days; that the meals are far between, and that the winkles spend their time between meals buried in the sand. The method of attack is described as follows: —

The couch (*Fulgur perversa* or *F. carica*) grasps the *Venus* in the hollow of its foot, bringing the margin of the *Venus* shell against its own shell margin. By contracting the columellar muscle it forces the margins of the shell together, which results in a small fragment being chipped from the shell of *Venus*. This is repeated many times, and finally the crack between the valves is enlarged to a width of 3 millimeters or more.

The proboscis is normally about 5 millimeters to 8 millimeters in diameter. There are three ways in which it may get at the animal. First, it may flatten out its proboscis so that it will go through the crack; secondly, it may pour in a secretion between the valves which kills the clam; and thirdly, it may wedge its shell between the valves of the *Venus*, and by contracting the columellar muscle actually wedge the valves apart.

(4) *The Starfish.* — The starfish is the least effective of the four active enemies of the quahaug, as it is not able to readily attack the quahaug in its burrow. A large starfish, which was found in one of the experimental boxes at Monomoy Point, had eaten a number of the quahaugs which were buried under the sand. The starfish evidently was able to get at the animals by working its "arms" in the coarse sand until the quahaug was exposed, and then opening it in the same manner as the oyster, by the steady pressure of the tube feet on the two valves of the quahaug. Quahaugs lying outside the sand are rapidly devoured by the starfish, which, after forcing the valves apart, passes its everted stomach into the shell and digests the contents. Under natural conditions it is probable that little damage is accomplished by the starfish, owing to the difficulty of getting at the quahaugs.

QUAHAUG CULTURE.

The Decline.

For decades the tidal flats and waters of the seacoast have yielded valuable harvests of shellfish, and the free-fishing public have continued their campaign of spoliation under the impression that these fertile territories were inexhaustible. As the thickly bedded areas near the beaches were exhausted, the quahaug fishermen ventured into the deeper waters, which greatly increased the cost and difficulties of fishing. The deep-water beds which opened a new era of prosperity for the quahaug industry, are now beginning to show the effects of the severe

systematic fishery which has prevailed for the past few years. There can be but one logical outcome to the present system, *i.e.,* the commercial extinction of the quahaug.

The serious nature of this decline has only recently been brought to the attention of the public, although many have noticed the increased cost of shellfish and at times have experienced difficulty in procuring a sufficient supply. At present there is a widespread awakening throughout the Commonwealth in regard to the cost of living, and considerable interest has been shown in matters relating to the shellfisheries, with a view toward checking the decline by developing these important sources of public wealth.

The present quahaug industry is of comparatively recent growth. Although known as an article of food by the early settlers ever since the time of the Pilgrims, the quahaug did not attain universal popularity until within the last thirty years, when the opening of inland markets increased the demand. The resultant high prices naturally caused a large number of men to venture into the industry, stimulated by the hope of handsome profits. Soon there came a time when the natural increase of the fertile quahaug beds failed to equal the annual harvest, and a gradual decline set in, which has attained such magnitude as to threaten the extinction of a most important shore industry, assuming such serious proportions in many of our coast towns as to thoroughly alarm the citizens. In Buzzard's Bay, a natural habitat of the quahaug, the industry in at least half the towns has declined to the point of commercial extinction, and even in the communities where it still retains some foothold, its existence is due to the development of new areas in the deeper waters. Conditions in many localities on Cape Cod are scarcely better. Wellfleet, one of the leading towns of the Commonwealth in the production of quahaugs, presents a typical case of this kind. Practically the entire population, directly or indirectly, depends upon this industry for a livelihood. The quahaug fleet, comprising nearly a hundred boats of all sizes, which may be seen every fair summer day fishing in various parts of the bay, is fast depleting the large natural beds of this region, and already the inhabitants are becoming apprehensive of the exhaustion of these areas. Similar conditions prevail to a greater or less degree in most of the villages of Cape Cod, and serious complications would doubtless follow the destruction of the quahaug fishery.

Indications of Decline. — So universal has this decline become that it is hardly necessary to enumerate proofs of its existence. As already stated, the industry has been practically exterminated in many of the coast towns, while in others the natural supply is but a remnant of its former abundance, and there are but few localities where the yield of the natural beds has not decreased more or less. No one can question that the decline in the quahaug industry is general, and that its

proper adjustment, as one of the great resources of the Commonwealth, is an important economic problem.

Rise in Price. — When the demand for any commodity increases, it is a law of economics that a rise in price will follow. We have seen how the demand for quahaugs has increased during the past twenty years. It was inevitable that there should be a rise in price. The development of the "little neck" (small quahaug) trade was the forerunner of the introduction of the larger quahaug. The increase in the price, while in part the result of an increasing demand, is also a sign of a decreasing supply. When the supply of a desirable commodity diminishes, the price advances, until a new equilibrium is established. Therefore, both supply and demand have combined to place the price of the quahaug at its present high figure.

Cause of the Decline. — In considering the present unsatisfactory conditions in the quahaug industry no one cause can be designated as having brought about this decline, but rather it has been the result of the combination of several important factors. The primary reason has undoubtedly been overfishing, a fact generally accepted throughout the fishing communities of the State. So long as the natural increase of the quahaug equals the amount taken from the flats it is clearly evident that the supply will not diminish. As soon, however, as the demand of the market necessitates a constantly greater annual production, the balance of nature is upset, and a diminution of the natural supply takes place. As we have already seen, the simultaneous decrease in the supply and increase in the demand caused a rise in the price, sufficient for a time to lure more men into the industry. This time of prosperity has already passed, and many men are leaving the fishery to seek a livelihood in other pursuits, as, in spite of the high prices, they are unable any longer to make a living. The discovery of large quahaug beds in the deep water was the only factor that prevented the destruction of the quahaug fishery long ago. These beds are now being overfished, and when they are depleted the disappearance of this great industry will be complete.

While the immediate cause of the decline is undoubtedly, and always has been, overfishing, the real cause lies in the conditions which tolerated such a system of spoliation, and allowed it to continue unchecked after its destructive features had long been apparent.

Under the old laws governing the fisheries of the Commonwealth, the State originally held possession of and exercised authority over all tidal waters as public property for every citizen. Later there arose a widespread feeling that the communities whose lands bordered on the ocean should have first right over these valuable territories. This feeling on account of the conditions of that time, met with little opposition, as transportation was slow and the people from the inland communities had not the same opportunities for utilizing the fishing privileges that the inhabitants of the coast towns possessed. Thus

the rights of the Commonwealth over the shellfisheries came to be vested in the individual seacoast towns. According to the original act the selectmen of every coast town were given certain privileges of supervision over the shellfish interests within its borders. The Legislature, however, was careful to specify that every inhabitant of the Commonwealth could still continue to take shellfish for family use or three bushels for bait per day in any part of the coast, in this manner reserving an important privilege for the public.

As this privilege has never been exercised to any extent for market purposes, the towns have had absolute control of the shellfisheries for years. Their authority has been a direct trust from the Commonwealth, and if the decline of the shellfisheries has been attributable to improper legislation, or lack of legislation, this responsibility rests wholly upon the seacoast towns. Let us see in what manner these towns have improved the valuable privileges, and how they have guarded the sacred trust conferred upon them by the Commonwealth. The past record of the majority of the towns fails to show any consistent effort on their part to safeguard or develop these industries. A few communities have made certain short-lived attempts to foster or protect their native resources, but in every important instance these efforts have proved either wholly inadequate, or, if possessing the qualities of success, have been abandoned without sufficient trial. The usual type of reform attempted by the towns has been restrictive legislation, which has aimed in an illogical and ineffectual manner to check the exploitation of the natural beds rather than provide methods of increasing the supply. Legislation of this kind has never proved a success in any important instance. It has been unpopular, difficult to enforce and thoroughly unadapted to effect the intended reform. It is inherently a false or mistaken policy. The shellfisheries have needed laws of a constructive nature, designed to develop the industry. Restrictive legislation unless accompanied by constructive is never truly protective, and in the past has proved such an unqualified failure as to be abandoned by its former advocates. It is not the purpose of this paper to criticise harshly the evidently well-meant efforts of the towns to benefit the shellfisheries, but it is universally conceded that they have in most cases proved a failure. It is not necessary to go into detail in the investigation of the various attempts of the towns in this direction, as they have taken in almost all cases the form of a close season over some specified areas, and few attempts to build up the natural resources have ever been honestly attempted. In the case of the quahaug fishing, we find that the efforts of the towns to keep the supply from becoming depleted have never been more than the most half-hearted attempts, and we are forced to conclude that the towns have dealt badly with the trust reposed in them by the Commonwealth, and have neglected the great opportunities for improving and preserving the natural quahaug beds.

It is only fair to state that the system of town control is ill calculated to produce the best results. It is not reasonable to suppose that a number of municipalities, working independently, should be able to evolve a unified system. It is, however, just cause for surprise that the Commonwealth has so long allowed such mismanagement. It is certainly a most pressing need that this old, cumbersome policy should give place to a more unified and successful system.

Under the present system of free fishing no constructive legislation can be applied, as there is no incentive for individual effort. The fishermen who advocate cultural methods and conservation of the natural resources are powerless through the indifference of others, and consequently are forced, against their will, to join the campaign of spoliation under the argument that they may as well get their share as long as the supply lasts. In this way the present system puts a premium on personal greed and discourages individual effort. It is practically impossible for legislation to check lawless exploitation where valuable resources are thrown open to the public. The unreasoning element will inevitably abuse the privilege to the utmost limit, and the more thoughtful will be swept into tacit consent. Naturally it would be for the general welfare for every fisherman to do his best to better conditions, but under the present system this rule could not hold, as no man, no matter how much a philanthropist, will work hard for the betterment of conditions only to see the results of his work appropriated by another.

The Remedy.

We have pointed out that the attempts by which the towns endeavored to stop the decline of the quahaug supply were all of a restrictive nature, designed to check the demand rather than to increase the supply. The true remedy is to be found in legislation which will permit the application of cultural methods. There are only two methods by which constructive laws can operate: (1) seeding the public waters and flats at the expense of the towns or of the State; (2) the introduction of a system of private grants.

(1) While there has never been any effort on the part of the towns or of the State to seed extensive tracts of quahaug territory, there have been attempts in the case of the soft-shelled clam. Such communal clam culture has generally failed, as the planting was usually in the hands of men unaccustomed to such work and ignorant of the proper methods. While successful communal culture can be carried on, there will always remain the natural drawbacks to any altruistic scheme of this sort, such as expense, uncertainty and non-co-operation, which tend to make it impracticable.

(2) The proposed remedy for preserving the native quahaug beds and developing the industry to its normal status is based upon a system of grants held and operated by individuals. Under this system an inhabitant of the Commonwealth would be permitted to lease a grant

of limited area from the State or town for a term of years, provisional upon the efficiency with which he improves his holding, and be guaranteed immunity from outside molestation. For this privilege he would pay a reasonable annual rental to the Commonwealth or town in addition to the taxes which would be levied by the town upon the value of his holdings. A system of this sort, which would allow a part of the waters in each town to become rented property, while the remainder, at least half the present area, should exist as public property, would so benefit the industry that the annual production for the rented part alone would doubtless exceed the present output for the whole under existing conditions. This proposed remedy has been the outgrowth of a long series of experiments on the part of the Massachusetts Department of Fisheries and Game. These experiments have aimed throughout to formulate a practical remedy for the prevailing evils. The experiments in question have shown conclusively that quahaug seed can be successfully transplanted from one locality to another, and that it can be made to grow to a marketable size with a small outlay of capital in a sufficient time to yield large returns. Not only have these experiments, conducted in varied environments in our coast waters, proved that this remedy contains the necessary elements of success, but a study of the industry as a whole has shown that it is the only remedy which can bring about the desired results. The proposed remedy is not a theory evolved on the spur of the moment, but is the outgrowth of several years of careful study of the prevailing conditions along our coast. It is a system based on the results of successful experiments, and has been placed on a practical, commercial basis with the oyster, both abroad and in the United States.

Benefits. — (1) It will save the declining industry by lessening the drain on the natural beds and by meeting the increasing demands of the market. Moreover, the "spawners" on the grants will in all probability suffice to abundantly seed all the public ground, at least to a greater degree than at present.

(2) It will increase the supply to more adequately meet the demands of the market. The quahaug has become a popular article of diet and there is no reason why it should not be a far more important item in the food supply of the Commonwealth than it is at present. In Massachusetts, where the population is so dense that it has to depend in great measure on other sections of the country for its supply of foodstuffs, any important article of food native to the Commonwealth should be well cared for.

(3) It would furnish more remunerative and steady work for the fishermen. This result would be accomplished in two ways: it would increase the supply of shellfish on the flats and tidal waters, held in common as already explained, thus increasing the catch of the average fisherman. But of greater value to the fisherman would be the privilege of holding a small piece of territory as his own property, which

should, under favorable circumstances, yield him a considerable annual income.

(4) It would be a benefit to the coast communities, where the shellfish industry furnishes the main income of the inhabitants. Under present conditions these communities depend for support on an uncertain industry, the revenue from which is extremely variable. Under these discouraging conditions many fishermen live literally from day to day, barely tiding over the severe winters with the money earned during the summer's fishing. The proposed system would do away in a great measure with this unsatisfactory state of affairs, as it would practically assure to every industrious quahauger a steady income.

(5) It would furnish a more abundant sea food for the public. Any undertaking which will result in increasing the supply is desirable from an economic standpoint. The quahaug as an article of diet has had a favorable reputation for some years. Its popularity is steadily growing and anything which would tend to increase the supply must be considered a public benefit.

(6) It would utilize thousands of acres of barren land now lying idle and unproductive. It has been a wise policy of this country for many years, fostered by men who have the national interests at heart, to conserve the natural resources and bring them to their highest degree of usefulness. In Massachusetts, not primarily an agricultural State, large tracts of territory, which in the fertile western countries would never be touched, are nevertheless, by careful tillage, made to yield profitable returns. It seems poorly in accord with the prevailing methods of thrift that large areas along our shore, which are more valuable acre for acre than any upland, should be allowed to remain unproductive, when they could, with a comparatively slight expenditure of time and money, be made to yield substantial returns. It is inconceivable that such a misguided policy can much longer control the shellfisheries. Already the matter has attracted popular attention, and will soon be dealt with in the same progressive spirit which Massachusetts has ever shown in the management of her industries.

Quahaug Farming.

Under the proposed system of quahaug culture the available territory comprising the tidal flats and shallow waters of our coasts would be dotted with small areas under artificial cultivation. There would be a striking similarity in this arrangement to a tract of agricultural country where fertile gardens are interspersed with stretches of meadow and pasture land. There can be no question that the system which holds sway over the agricultural districts of our country is equally desirable for our extensive shore areas, which now produce but a portion of their normal yield. If these tracts could be divided, in part at least, into small plots of cultivated ground, nature would be greatly assisted in her efforts to render these territories productive.

That we may see to what degree the installation of such a system would affect the industry, let us take one of these proposed cultivated plots or grants to serve as a model. The average fisherman, an industrious family man, would take out one of these little grants. At first he would not depend very much on the income derived in this manner, but would probably continue to fish on the public grounds. Gradually, as he became accustomed to its management, he would come to look more and more to his own leased territory for a livelihood. He would be constantly on the outlook in his trips around the bays and coves of his home district for little "pocket" beds of small quahaugs, where he could procure seed for his grant. He would carry this seed carefully home with him, and experiment, with ever-increasing interest, in planting so as to insure the least loss and greatest gain. He would be ever anxious to see how his novel harvest was maturing, looking over his bed from time to time to note the growth of the seed, and to remove cockles and other enemies. If his little farm were located between tide lines he would be careful to have his seed planted early in the spring, and would in most cases harvest the entire crop late in the fall or early winter, before it suffered exposure to the ice. If his grant were situated just below mean low-water mark, where it would never be exposed, he could probably allow his seed to remain for two seasons, when it would yield a still better profit. But wherever situated, on soil at all suitable, he would possess in his little holding of an acre or more property of such value that he would be able, under normal conditions, to reap enough to support his family in very comfortable circumstances. He would be able to do this with far less expense of time and labor than enterprises of this sort usually require. While his grant would in every material respect be a miniature farm, and would probably be known as such, it would be entirely free from most of the labor involved in the care of the ordinary farm. No time would have to be devoted to the work of plowing, harrowing or weeding, which makes the life of the average farmer such a hard-working existence. There would be none of the expense and labor of fertilizing, so necessary for the success of upland gardening; there would be little or no time required in fighting the natural enemies of the growing crop which the upland farmer experiences. The quahaug has few enemies, and these do little damage, and are, besides, easy to fight. The fisherman-farmer would be free from anxiety on account of the weather, over which his more unfortunate neighbor of the upland so constantly worries. No drought, beating rain or early frost is likely to injure his growing crop. Practically the only labor required is that of seeding and harvesting, which are simpler and easier for the shellfish culturist than for the farmer. The ordinary farmer is frequently content to reap from his average acre of cultivated ground from \$20 to \$50. The quahaug planter on an equal territory could raise

many times that amount as under favorable circumstances $750 net may be realized annually from one acre.

The comparison is strikingly in favor of the quahaug grant, and the benefit of such a system is sure to follow for all coast communities. The shellfisherman is raised from an uncertain livelihood to a position of secure and comfortable independence, the communities made more prosperous and a decadent industry revived.

History of Quahaug Farming. — Until within recent years few attempts at quahaug culture have been made in Massachusetts, although for some time oystermen in the States directly south have carried on successful planting. The demand for small seed has extended even to Massachusetts, and many thousand bushels have been shipped out of the State for planting purposes. Nantucket, Chatham, and finally New Bedford have taken their turn in this traffic, according to the abundance of small quahaugs. In 1909 one New York planter is authentically reported to have purchased nearly 5,000 bushels of seed from Massachusetts, paying $3 per bushel. During 1909 the shipment of seed from New Bedford and Fairhaven approximated 45,000 bushels. These small quahaugs are replanted in Long Island waters, and in one year's time, according to the results of growth experiments, probably netted the planter at least 4 bushels of marketable little necks for every bushel planted. Lately some of the Massachusetts oystermen have successfully raised quahaugs on their oyster grants, and are ready to engage in a more extensive way.

The first legislative act permitting the planting of quahaugs was passed for the Narragansett Bay section in 1874. This legislation permitted the giving of licenses for the planting of shellfish in the town bordering on Mount Hope Bay. Nothing was accomplished, however, as the law was repealed the following year. The second movement took the form of a special law permitting the bedding of quahaugs in Eastham, Orleans and Wellfleet in 1904, which in fact was a semi-license. Finally, in 1909 a general law was passed, which gave local option to the coast towns in the giving of grants. As yet these laws appear to be without result. The "bedding" act was utilized to some extent to hold quahaugs for market, and in a few cases for growing purposes. No town has as yet taken advantage of the general law. What culture has been carried on has been done secretly or on the oyster grants, where protection is given. Under these adverse conditions planting has proved remunerative, and there is every indication that, when absolute protection is guaranteed the culturist, a flourishing industry will be inaugurated.

Possibilities of Quahaug Farming. — While the subject of clam farming has received a great deal of attention, people have failed to see that the same cultural methods can be employed even to greater advantage with the quahaug. A quahaug farm, if properly tended,

should yield more revenue, acre for acre, than any clam flat, and prove a much safer investment for the planter. If it were not for the scarcity of seed at the present time, quahaug culture, although confined to the southern waters of the Commonwealth, would become the greatest of the shellfish industries of Massachusetts.

The quahaug has a wide range; it is found in all depths of water, from the high-tide line to a depth of more than 50 feet, and in various kinds of bottom. This natural adaptability gives the quahaug a wider area than any other commercial shellfish, as it will live in almost any soil, although the rate of growth depends essentially upon its location in respect to current. Vast areas, over 25,000 acres, on the southern shores of Massachusetts, at present unproductive except for here and there small scattering beds, can be utilized for shellfish farms, which, when placed under cultural methods, should yield many times the present production and furnish a livelihood for thousands of men. Quahaugs will grow on such areas as the Common Flats of Chatham, if they are planted and properly cared for. Instance after instance can be cited where the territory is so extensive that if every inhabitant of that particular locality were allotted a grant of two or three acres, the leased portion would be but a small part of the whole area. It is conservation of our natural resources in the truest sense to make use of the great undeveloped possibilities of our shore waters.

Methods of Operating a Quahaug Farm.

Selecting the Ground. — The planter should have two main ideas in mind in choosing the location of his grant: (1) facilities for work and marketing; (2) productive capacity. The ideal grant combines the two, where the work is easy and the growth rapid, while a near-by market furnishes high prices. Unfortunately, such delightful combinations are few, and the culturist will have to choose a grant with such qualifications as he thinks best suited to his needs. For this reason it is desirable to consider these points more in detail.

(1) Facilities for work comprise three things: (*a*) The accessibility of the grant to the home of the culturist, where he can get to it without loss of time and where he can have a protective oversight. The term "home" is used here in the sense of landing place, boat mooring or shellfish shanty, where the culturist keeps his equipment. (*b*) The depth of water over the bed, and the nature of the bottom, as raking in shallow water is much easier and less expensive as to time and implements than the deep-water quahauging, while the firmness of the bottom increases the work of raking. If, perchance, the grant is between the tide lines the labor of harvesting the quahaugs is less than if they were continually covered by water, but in such a case the working period is limited, and the quahaug culturist risks the destruction of his crop during the winter. (*c*) The ease of marketing is another

factor, as distance and poor transportation facilities add to the expense. The planter must consider the question of bringing his produce as cheaply as possible to the railroad.

(2) The most important factor in the selection of the ground is its productive capacity. The prime requisite of a grant is a rapid rate of growth, which, for a grant situated below mean low-water mark, depends upon two conditions, — the current or circulation of water and the nature of the soil. In the case of the few grants existing either permanently or temporarily between the tide lines, a third condition, exposure, demands attention, as the time of exposure at low tide reduces the feeding period of the quahaug. As the majority of the grants will be below low-water mark the other two conditions are more important.

(*a*) *Soil.* — The nature of the soil affects the quahaug in two ways: (1) if too shifting it buries the quahaug or washes it beyond the border of the grant; (2) soils in which organic acids, caused by the decay of plant life, are present, prove unsatisfactory for any catching of seed, interfere to a slight extent with the growth by destroying the shell, and worst of all, give the quahaug a poor, black appearance, unfavorable for immediate marketing. While the effect of soils on shell formation has never been worked out, and although the quahaug derives its material for its shell from the water, nevertheless, the nature of the soil in some indirect way determines the appearance, the composition and the weight of the shell, as observations on quahaugs from various soils in near-by localities indicate.

(*b*) *Current.* — The growth of the quahaug depends upon the circulation of water, as the current is the "food carrier," and therefore, within limits, the more current, the more food. Current also keeps the ground clean, and prevents contamination or disease from spreading. The most important point in choosing the ground is to locate the grant where there is a good current, as growth is directly proportional to the circulation of the water. It is possible, of course, for a place to have so rapid a current that it would cause a shifting of the bottom, and perhaps wash the quahaugs from their burrows, but such a current is found in but few localities in which one would think of planting.

There are several other factors which do not influence the growth directly but at the same time have more or less influence upon the productive qualities of the grant.

(*c*) *Pollution.* — It is hardly necessary to more than mention the danger to public health and the depreciation in the value of the marketed quahaugs when it is publicly known that the grant is situated in contaminated waters. For purely business reasons the planter should ascertain the purity of the water in the locality of his proposed grant, as in the future the public will demand the closure of all polluted waters and discountenance the sale of shellfish from such sources.

(*d*) The proximity of localities where seed quahaugs may be readily

obtained, should be considered, as the cost of obtaining the necessary stock is an important item. If the grant can be situated in the vicinity of a natural quahaug bar, where seed can be obtained from the natural set, it will prove advantageous. If a method of artificial hatching of the seed, either from the egg or by spat collecting, is successfully placed on a commercial basis, such a precaution will not be necessary, as the quahaug culturist, like the oysterman, will be able to raise his own seed.

(*e*) Closely connected with the study of the food of the quahaug comes the question of flavor of the meat, an important item in marketing. It is a well-known fact that quahaugs from various localities have different flavors, and in the future there will be a greater use of trade names and special brands, based on this fact. The flavor of a quahaug depends upon its environment, and, although it has not been absolutely proved, evidence points to the fact that the different flavors are due to the different kinds of plant food. In the future, when more practical knowledge is obtained about the food of these animals, it may be possible to supply special flavors by artificial cultures of food. Another factor determining the condition of the meats is the presence of oils, chemicals, etc., from factory wastes, which sometimes renders the shellfish unsavory. The soil and the silt in the water may also influence the flavor.

(*f*) The grant should be chosen in a well-protected locality. Natural conditions, such as loose sand, exposure to winds and choppy seas, increase both the loss of stock and difficulty of labor. Masses of floating eelgrass in some places are strewn over the bottom by storms, interfering with the growth and increasing the labor. Fortunately, the quahaug is hardy, and is not affected to any great extent by the elements, except when the grant is located between the tide lines. A grant between the tide lines or close to low-water mark is an uncertain investment, as there is always danger of destruction during a severe winter, either by the ice or frost. The danger is not so much in the freezing of the quahaug as it is in the sudden thawing. If frozen quahaugs are slowly thawed out they will assume normal functions, as if nothing had happened, but when thawed out quickly many perish. From observation it can be said that in a fairly protected locality, where the grant is not too high between the tide lines, the chances of loss from winter will not be more than one case out of seven.

In some localities there may occur a slight loss from the winkle, a natural enemy of the quahaug. The culturist can, by more or less labor, according to their abundance, keep them off his property. As the winkle is valuable for bait, the actual loss of time will be minimized, and even if unmolested the damage will be slight.

The rule for choosing a grant should be: bottom of a mixture of mud and sand (exact nature of soil not important); clear of eelgrass,

especially thick eelgrass; water the depth of 3 feet or more at low tide; a *good current;* and such facilities for work as best suits the particular planter.

Obtaining the Seed. — Nature has not provided so abundant a means of stocking the quahaug farms as is the case with the clam. The set of quahaugs is more scattering and apparently less abundant. In nature this is not necessary, because the young quahaugs after once they have taken refuge in the sand, are more hardy than the young clams, which perish in great numbers. Occasionally natural sets will be found in limited localities, as Stony Bar, Wellfleet; Mill Pond, Chatham; Acushnet River, etc. From these places the seed must be obtained. At the present writing Acushnet River and Tuckernuck Island have large beds of seed, which the inhabitants are industriously shipping to planters outside the Commonwealth. As these beds vary, occurring in different sections in succeeding years, the natural seed must be purchased from the specially favored localities. Small quahaugs can also be obtained from Prince Edward Island, and probably from the Southern States.

The planters might experiment in catching seed by simulating the natural conditions of the seed bars on their grants, and turn their grounds into spat collectors. By the combined efforts of interested planters it would not be many years before a practical method of spat collecting could be devised. As the object of most planters would be the production of "little necks," the size for planting would be under the maximum market "little neck."

Planting. — The grant needs little preparation for planting. After the bounds are marked according to the regulations, thick eelgrass, stones and other débris which would interfere with the raking, and enemies such as winkles, should be gradually removed, either before planting or in the work of harvesting. The planting of the small quahaugs is a simple matter. It should take place preferably before May 1, when the quahaug begins its summer growth, but as seed is scarce, the planter will probably plant whenever he can procure the young. The quahaugs should be scattered evenly from a boat by shovels such as the oyster planters use, or it can be done in any way most convenient for the culturist. Ordinarily the quahaugs will burrow in the sand in a short time after they settle to the bottom. As their activity depends to a great extent on the temperature of the water, it is not advisable to plant in cold weather, as the quahaugs, instead of burrowing, will lie exposed on the surface, where they are in danger of perishing. The amount of seed that can be planted on any given area depends upon the natural conditions, chiefly the current. As many as 20 to the square foot can be bedded when the circulation is good, while the number should be decreased or increased according to the speed of the current. The planter, after a year or two, will be able to determine the exact number he can plant on his grant to the best advantage.

Working the Grant. — The work of caring for the grant will entail but slight labor. No cultivation of the ground is required, as in the upland farm, and the quahaug is left undisturbed until it has attained marketable size. A certain amount of oversight will be necessary to keep off poachers, and time must be given to destroy enemies and clean away any dead seaweed that drifts upon the grant, but further precautions are unnecessary.

Harvesting. — The principal labor comes in the harvesting of the crop, which must be done by raking or tonging. The location and natural conditions of the grant make this a variable factor, as depth of water, hardness of bottom and exposure to rough water increase the difficulty of raking. While a certain portion of the crop may be taken at any season, the greater part will be marketed in the fall, when the season of raking on the natural beds is nearing a close, in order to get the advantage of the full summer's growth and the better winter prices. The fall work will apply only to the more protected grants which permit work in rough weather. The planter will have his grant divided into sections according to the size of the planted seed, which will be assigned in lots according to size and length of time before marketing. By dividing the ground into three or more parts, planted with quahaugs of different sizes, the culturist will have a sort of rotation of crops, cleaning up and replanting one-third of his property each year. In this way the planter will be able to place a uniform size on the market and receive a proportionately better price for his goods. There will be less labor in culling, and the "little necks" can be shipped directly in barrels or bags to special customers.

The Value of a Quahaug Farm. — An acre of "little-neck" quahaugs has a high market value. A conservative estimate of 10 per square foot gives an annual yield of 600 bushels of 2½-inch quahaugs per acre. This assumes that 120 bushels of 1¾-inch quahaugs were planted to the acre. The price paid for the same, at the high price of $5 per bushel, would be $600. The price received for the same, at $3 per bushel, would be $1,800, or a return of $3 for every $1 invested. This is a conservative estimate on all sides. Quahaugs could be planted two or three times as thick, seed might be purchased for less money, more money might be received for private shipments, and faster growth can be obtained. Practically the only labor necessary is gathering the quahaugs for market. The quahaug farm requires no such care as the agricultural farm, and offers far more profit.

Perhaps the greatest advantage to the fisherman, next to the amount of quahaugs he can produce from his grant, is the fact that he is independent of the market. The value of the present quahaug industry lies chiefly in the production of "little necks," which could be made a specialty under a cultural system. The planter can market his quahaugs at whatever size and whatever time he desires, and is not forced to ship during periods of low prices, as he can leave his quahaugs

bedded on his grant. At the present time the quahaugers, except in a few towns where there are "bedding rights," are forced to ship their catch as soon as taken, and receive often a low market price. In this way the planters could regulate, to a great extent, the market price for their own benefit.

Advantage of a Uniform Size. — At the present time there is much dissatisfaction among the quahaug fishermen who rake on the natural beds because they receive poor prices. From the fisherman's standpoint the dealer is to blame, as it is claimed that he is continually trying to increase the middleman's profits. From the point of view of the shellfish dealer the fault seems to be with the fisherman, who does not carefully select his stock for market. A dealer is bound to pay better prices for uniform and selected stock. The common practice is to ship as "little necks" quahaugs of all sizes from 1¼ to 3 inches, large and small promiscuously scattered through the barrel, or first a barrel of large, then small, with the result that in most cases the dealer knows not what to expect, and naturally gives a minimum price. Perhaps with more care on the part of the quahauger this circumstance might be improved to some extent; but the fault lies rather in the present method of fishing. The logical method of increasing the price is the steady shipment of uniformly selected stock. This is entirely impossible under free-for-all fishing. Steady orders cannot be filled when raking is irregular; a uniform size cannot be shipped, owing to the varied yield of the natural beds; and the quahaugs, unless bedded as in Orleans, Wellfleet and Eastham, must be shipped for whatever price is offered. Quahaug culture with its grant system offers a remedy, and furnishes to the quahauger a means of controlling the market. In contrast to the free fishery, the yield from the quahaug farm is steady instead of irregular; only quahaugs of the maximum market size, necessarily uniform, need be shipped, and the best prices obtained for them, while the quahauger is not forced to ship at a low price, but can wait until the market reaches his figure. As an illustration of the difference in price between ordinary shipped "little necks" from the natural fishery and uniformly selected stock from leased area, the following case is cited: from a locality on Cape Cod in 1909 quahaugs were shipped to market, the selected stock bringing $18 a barrel to the planter at any season, the ordinary stock, ranging from 1½ to 3 inches, only $10. No other proof is needed to show the advantage of a uniformly selected stock, such as can be obtained only by quahaug farming.

THE INDUSTRY.

From the standpoint of the fisherman the methods of capture and preparation of the quahaug for the market need no explanation; but the average reader, perhaps unfamiliar with the practical side, may find the following pages of interest. In order to give a complete

report upon the quahaug fishery, owing to the fact that such data may be of use in later years for comparative purposes, it has been necessary to include special parts of the mollusk report of 1909.

The Fishing Grounds.

The quahaug is essentially a southern or warm-water mollusk and Massachusetts practically marks the northern range of the fishery, although quahaugs are taken in the Gulf of St. Lawrence. As shown on the accompanying map (Fig. 30), only the southern waters of the Commonwealth are included in this fishery. For greater detail the reader is referred to the "Mollusk Report" of 1909.

The quahaug like the scallop territory can be arbitrarily separated into four main divisions: (1) the north side of Cape Cod; (2) the south side of Cape Cod; (3) Buzzard's Bay; (4) the Islands of Nantucket and Martha's Vineyard.

North Side of Cape Cod. — In this section Plymouth marks the northern range, as a few quahaugs are found in this harbor. Passing south, small beds are found in Barnstable harbor, while from Brewster north, in the waters of Orleans, Eastham and Wellfleet, the largest quahaug fishery of the Commonwealth is carried on. A few quahaugs are also found in Provincetown harbor and along the Truro shore. The chief characteristics of this section are: the great rise and fall of the tide, averaging about 10 feet, which leaves large areas of exposed flats; the swiftness of the tides, causing a shifting of the sand bars; and the great depth of the water over the quahaug beds.

Quahaugs are found both on the flats and in all depths of water, although the commercial fishery is carried on mostly in the deep water, with rakes ranging from 30 to 60 feet in length. The best beds are in the deep water, as the other localities have been fished out, the quahauging gradually extending to the deeper or the more exposed waters. Unfortunately, quahaugs can be taken only on moderate days, as rough water interferes with raking, and the quahauger who can average four working days a week is considered fortunate. In this section the basket rake shown in Fig. 59 is used. Quahaugs are taken also with ordinary clam or garden rakes on the flats at low water, especially in the harbors during the low course tides. About 8,000 acres are included in this section.

(*a*) *Barnstable Harbor.* — In Barnstable harbor, on the north side of the town, a few quahaugs are found in isolated patches, which are of small commercial importance. In the future the vast barren flats may be made productive of quahaugs as well as clams, although at present the total area of the quahauging grounds is hardly 5 acres.

(*b*) *Orleans and Brewster.* — The fishery is conducted in the deep water, with the basket rake. The area comprises about 1,000 acres in Cape Cod Bay, and about 500 in Pleasant Bay, on the east side of the two towns.

(*c*) *Eastham.* — The quahaug territory comprises about 4,000 acres, extending from the shore for a distance of nearly 3 miles. While scattering quahaugs, largely blunts, are found over the entire area, the fishery is conducted only at certain places. In 1910 a thickly set bed of quahaugs was discovered south of Billingsgate Island. The question of town jurisdiction over this bed has caused the towns of Wellfleet and Eastham much legal dispute, court expense and hard feeling — another instance of the insufficiency of the present method of town shellfish regulation.

(*d*) *Wellfleet.* — The quahaug territory of Wellfleet comprises about 2,500 acres, and approximately takes up all the harbor, wherever there are no oyster grants, running from the "Deep Hole," between Great Island and Indian Neck, southward to the Eastham line. Outside these limits a few quahaugs are found on the flats of Duck Creek and along the shore. They are more abundant on the north side of Egg Island, where they are taken in shallow water with ordinary hand rakes. The best quahauging is found in the channel, extending from an imaginary line between Lieutenant's Island and Great Beach Hill south to Billingsgate and beyond. Here the greatest depth at low tide is 4½ fathoms, with a general average of 3 fathoms. Raking is done with long-handled basket rakes.

(*e*) *Provincetown.* — No commercial fishery is carried on. A few quahaugs, chiefly little necks, are found in the tide pools among the thatch on the northwestern side of the harbor.

South Side of Cape Cod. — This section, comprising the towns on the south side of Cape Cod from Chatham to Falmouth, ranging in order, from east to west, Chatham, Harwich, Dennis, Yarmouth, Barnstable, Mashpee and Falmouth, has less territory, about 5,000 acres, and produces only one-fifth of the yield on the north side of the Cape. While this section is favorable for the scallop, quahaugs are not found in any great numbers on the exposed waters on the Sound side, and the grounds are mostly confined, except in the case of the Common Flats of Chatham, to the enclosed bays and harbors, such as Pleasant Bay, Lewis Bay, Osterville Bay, Waquoit Bay, etc. Natural conditions are somewhat different than on the north side, as the rise and fall of the tide is slight, about 2 feet, and, owing to the sheltered conditions, raking can be carried on at all times during the summer months. The shallow water permits easier raking and the use of shorter handled rakes. Basket, claw and garden rakes are used, although the greater part of the commercial fishery is conducted with the basket type.

(*a*) *Chatham.* — Chatham is favorably situated in regard to the quahaug fishery, as this shellfish is found in the waters on the north and south sides of the town. The grounds are extensive, covering about 2,000 acres, the greater part of which consists of the vast area south of the town, known as the Common Flats. The quahauging grounds

are in four localities: (1) Pleasant Bay; (2) Mill Pond; (3) Stage harbor; (4) Common Flats.

(*b*) *Harwich.* — Harwich shares with Chatham and Orleans the quahaug fishery of Pleasant Bay, but has a more limited territory, as only a small portion of Pleasant Bay lies within the town limits. Practically all this territory, comprising 100 acres, is quahauging ground, though the commercial quahauging is prosecuted over an area of 10 acres only. Scattering quahaugs are found over an area of 100 acres. In the southern waters of the town, on the Sound side, scattering quahaugs are found in certain localities, but are not of any commercial importance. The most important of those localities are off Dean's Creek and in Herring River, where quahaugs are dug for home consumption.

(*c*) *Dennis and Yarmouth.* — The quahauging grounds, about 200 acres in area, are practically all in Bass River, where Dennis and Yarmouth have equal fishery rights.

(*d*) *Barnstable.* — The greater part of the quahaug industry is conducted on the south shore of the town, which is especially adapted, with its numerous inlets, for the growth of this shellfish. The principal fishery is in Cotuit harbor and West Bay, and is chiefly shared by the villages of Osterville, Marston's Mills and Cotuit, which lie on the east, north and west sides, respectively, of the bay. The principal area for quahauging is a flat along Oyster Island, comprising about 70 acres of sandy bottom, while directly west, in the center of the harbor, is a strip of 80 acres of mud and eelgrass where scallops and quahaugs abound. Scattering quahaugs are found in Osterville harbor, West Bay, Poponesset River and East Bay, comprising a total of 1,650 acres, of which part only is productive. At Hyannis the grounds are confined to Lewis Bay, where they cover an area of 800 acres. Quahaugs are found in scattered patches over this area, but in no place is quahauging especially good.

(*e*) *Mashpee.* — The best grounds are found in Poponesset Bay and river, where a territory of 200 acres includes several oyster grants, which are worked but little. On the east side of Waquoit Bay scattering quahaugs are found in Mashpee waters.

(*f*) *Falmouth.* — There is practically no quahaug industry in Falmouth. Hardly 100 bushels are dug annually, and those only for home consumption. A few quahaugs are perhaps shipped by the oystermen. Quahaugs are found mostly in scattering quantities over a large area in Waquoit Bay, and in small quantities on the north and west side of Great Pond, comprising a total of nearly 400 acres. Not all this ground is capable of producing quahaugs, but many parts could produce good harvests.

Buzzard's Bay. — The Buzzard's Bay section comprises the towns bordering on the bay, and includes the towns of Falmouth, Bourne,

Wareham, Marion, Mattapoisett, Fairhaven and New Bedford, covering an area of about 8,000 acres of quahauging territory. This section is naturally well adapted for the quahaug, as conditions are especially favorable for its habitation. The numerous inlets and bays, the medium rise and fall of the tide, the influx of the water as it courses in and out of the little bays and estuaries, together with its warmth and the abundance of food forms, renders Buzzard's Bay extremely well situated for the growth and propagation of the quahaug. This section shows the greatest effects of overfishing, as part of the beds have been almost exhausted and the remainder are under a severe strain. The quahaug can never be exterminated completely, as when the supply becomes scarce the number of men engaged in the fishery diminish, but it is comparatively easy to ruin the commercial industry. The natural adaptability of Buzzard's Bay will never fully be utilized until a system of quahaug planting is inaugurated, whereby nature will be assisted in the restocking of the depleted areas. Fishing is carried on with a variety of rakes, from an ordinary garden to the large basket rake.

(*a*) *Falmouth.* — Small patches of good quahaugs are found at North Falmouth, Squeteague Pond, West Falmouth harbor on the southeast side, and a few in Hadley harbor, Naushon.

(*b*) *Bourne.* — Situated at the head of Buzzard's Bay, and separated from the adjacent town of Wareham by Cohasset Narrows, Bourne has many advantages for a profitable quahaug industry. It possesses nearly twice as much quahaug territory as Wareham, but, as most of this is unproductive, has a smaller annual output. The territory includes over 2,500 acres of ground, most of which consists of flats of mud, sand and eelgrass, covered with shallow water. It is very sparsely set with quahaugs. Outside the oyster grants practically the entire stretch of coast from Buttermilk Bay to Wing's Neck is quahauging territory. Other grounds lie between Basset's Island, Scraggy Neck and Handy's Point.

(*c*) *Wareham.* — Quahaugs are found over practically the entire territory, and comprise a total area of about 1,300 acres. Although much of this area is barren, the commercial fishery is maintained by small isolated beds which occur here and there. The two principal centers of the industry are in Wareham River and Onset Bay. At Onset the whole bay, except the oyster grants, as included between the southeast end of Mashnee Island and Peter's Neck, is used for quahauging. A few quahaugs are found in Broad Cove, and fair digging is obtained in Buttermilk Bay and Cohasset Narrows. The Wareham River, outside the oyster grants, and a narrow shore strip from Weweantit River to Tempe's Knob, comprise the rest of the territory. In Onset channel a fine bed exists in deep water, 2 to 4 fathoms, but the ground is so hard that not much digging is done.

(*d*) *Marion.* — The quahaug territory, comprising a total of 400

acres, is chiefly confined to Marion harbor, running in a narrow strip parallel to the shore from Aucoot Cove all along the coast to Planting Island. Almost all the head of the harbor and all of Blankenship's and Planting Island Cove is quahaug area. Small grounds are also found at Wing's Cove and in the Weweantit River.

(*e*) *Mattapoisett.* — Quahaugs are very unevenly distributed over 800 acres. The best quahaugs are found in Aucoot Cove and at Brants. In the main harbor scattering quahaugs are found.

(*f*) *Fairhaven.* — Some 3,000 acres are more or less bedded with quahaugs. Of this, probably not more than one-tenth is very productive. The best quahauging is in Acushnet River, where digging for market has been forbidden because of sewage pollution (see New Bedford), and in Priest's Cove as far as Sconticut Neck. In these grounds "little necks" are numerous. The grounds around West Island and Long Island, once very productive, are now largely dug out. Little Bay and the east coast of Sconticut Neck are fairly productive, while the west coast yields only a small amount. Most of the quahaugs dug for food come from the deep water west-southwest of Sconticut Neck.

(*g*) *New Bedford.* — Good beds of quahaugs, particularly "little necks," exist in Acushnet River and Clark's Cove, but can be taken only for bait. As several sewers run into the Acushnet River, and the public health was endangered by the consumption as food of the quahaugs taken from the river and the waters near its mouth, nearly 400 acres of quahaug territory were closed by the State Board of Health. What little available territory there is outside the proscribed area, off Clark's Point, is free to all.

The Islands of Nantucket and Martha's Vineyard. — This section comprises valuable territory, especially in the production of "little necks." The grounds, approximating 7,000 acres, are found principally in Katama Bay, Edgartown, Nantucket harbor and near the Island of Tuckernuck. Conditions here resemble closely the south side of Cape Cod, as regards exposure, rise and fall of the tide, and depth of water.

(*a*) *Nantucket.* — Nantucket is especially adapted for quahaugs, as Nantucket harbor, Maddequet harbor and the Island of Tuckernuck possess extensive territory. The quahauging territory of Nantucket is divided into three sections: (1) Nantucket harbor; (2) Maddequet harbor; and (3) Tuckernuck. In Nantucket harbor quahaugs are found over an area of 2,290 acres, both scattering and in thick patches. Maddequet harbor, on the western end of the island, has approximately 300 acres suitable for quahaugs, running from Broad Creek to Eel Point. On the eastern end of Tuckernuck Island is a bed of quahaugs covering about 200 acres; while on the west side, between Muskeget and Tuckernuck, is a large area of 2,500 acres which is more or less productive. The Tuckernuck fishery is largely "little necks," and it is from here that the shipment of small seed quahaugs has been made.

(*b*) *Edgartown.* — The finest "little neck" fishery in Massachusetts is found in Katama Bay, in the town of Edgartown. Two-fifths of the entire catch are "little necks." The most productive grounds are situated in the lower part of Katama Bay, while quahaugs are also found in Edgartown harbor and in Cape Poge Pond, the total area of these localities comprising 1,800 acres.

Industrial Practices.

Methods of Capture. — Several methods of taking quahaugs are in vogue in Massachusetts, some simple and primitive, others more advanced and complex, but all modifications of simple raking or digging. These methods have arisen with the development of the industry, and record the historical changes in the quahaug fishery, as each new fishery or separate locality demands some modification of the usual methods.

(*a*) *"Treading."* — The early settlers in Massachusetts quickly learned from the Indians the primitive method of "treading" quahaugs, which required no implements except the hands and feet. The "treader" catches the quahaug by wading about in the water, feeling for them with his toes in the soft mud, and then picking them up by hand. Nowhere in Massachusetts is it used as a method of commercial fishery.

(*b*) *Tidal Flat Fishery.* — Often quahaugs are found on the exposed tidal flats, where they can sometimes be taken by hand, but more often with ordinary clam hoes or short rakes. Owing to the scarcity of quahaugs between the tide lines, this method does not pay for market fishing, and is resorted to only by people who dig for home consumption.

(*c*) *Tonging.* — In most parts of Buzzard's Bay and in a few places on Cape Cod quahaugs are taken with *oyster tongs*. This method is applicable only in water less than 12 feet deep, as the longest tongs measure but 16 feet. Four sizes of tongs are used, 8, 10, 12 and 16 feet in length. Tonging is carried on in the small coves and inlets, where there is little if any rough water. A muddy bottom is usually preferable, as a firm, hard soil increases the labor of manipulating the tongs, which are used in the same manner as in tonging oysters.

(*d*) *Raking.* — The most universal way of taking quahaugs is with rakes. This method is used in every quahaug locality in Massachusetts, each town having its special kind of rake. Four main types of rakes can be recognized: —

(1) *The Digger.* — In some localities, chiefly in Buzzard's Bay, the ordinary potato digger or rake, having four or five long, thin prongs, is used. Usually it has a back of wire netting, which holds the quahaugs when caught by the prongs. As the digger has a short handle of 5 feet, it can be used only in shallow water, where the quahauger, wading in the water, turns out the quahaugs with this narrow rake. This method yields but a scanty return, and is more often used for home consumption than for market.

(2) *The Garden Rake.* — The ordinary garden rake, equipped with a basket back of wire netting, is in more general use in shallow water, either by wading or from a boat, as it has the advantage of being wider than the potato digger.

(3) *The Claw Rake.* — This type of rake varies in size, width and length of handle. It is used chiefly at Nantucket. The usual style has a handle

6 feet long, while the iron part in the form of a claw or talon is 10 inches wide, with prongs 1 inch apart. Heavier rakes with longer handles are sometimes used for deep water, but for shallow water the usual form is the short-claw rake.

(4) *The Basket Rake.* — The greater part of the quahaug production is taken from deep water, with the basket rake. These rakes have handles running from 23 to 65 feet in length, according to the depth of water over the beds. Where the water is of various depths, several detachable handles of various lengths are used. At the end of these long handles is a small crosspiece, similar to the crosspiece of a lawn mower; this enables the quahauger to obtain a strong pull when raking. The handles are made of strong wood, and are very thin and flexible, not exceeding 1½ inches in diameter. The price of these handles varies according to the length, but the average price is about $2. As the long handles break very easily, great care must be taken in raking.

Three forms of the basket rake are used in Massachusetts. These rakes vary greatly in form and size, and it is merely a question of opinion which variety is the best, as all are made on the same general principle, — a curved, basket-shaped body, the bottom edge of which is set with thin steel teeth.

The Wellfleet and Chatham rake is perhaps the most generally used for all deep-water quahauging on Cape Cod, and finds favor with all. It consists of an iron framework, forming a curved bowl, the under edge of which is set with thin steel teeth varying in length from 2 to 4 inches, though usually 2½-inch teeth are the favorite. Formerly these teeth were made of iron, but owing to the rapid wear it was found necessary to make them of steel. Over the bowl of this rake, which is strengthened by side and cross pieces of iron, is fitted a twine net, which, like the net of a scallop dredge, drags behind the framework. An average rake has from 19 to 21 teeth, and weighs from 15 to 20 pounds.

The basket rake used at Edgartown and Nantucket is lighter and somewhat smaller than the Wellfleet rake. The whole rake, except the teeth, is made of iron. No netting is required, as thin iron wires ⅓ inch apart encircle lengthwise the whole basket, preventing the escape of any marketable quahaug, and at the same time allowing the mud to wash out. This rake has 16 steel teeth, 1½ inches long, fitted at intervals of 1 inch in the bottom scraping bar, which is 16 inches long; the depth of the basket is about 8 inches. Shorter poles, not exceeding 30 feet in length, are used, and the whole rake is much lighter. The price of this rake is $7.50, while the poles cost $1.50.

The third form of a basket rake is a cross between the basket and claw rakes. This rake is used both at Nantucket and on Cape Cod, but is not so popular as the other types. The basket is formed by the curve of the prongs, which are held together by two long cross-bars at the top and bottom of the basket, while the ends are enclosed by short strips of iron. This rake exemplifies the transition stage between the claw and basket types, indicating that the basket form was derived from the former. Handles 20 to 30 feet long are generally used with these rakes.

Shallow v. *Deep Water Quahauging.* — Two kinds of quahauging are found in Massachusetts, — the deep and the shallow water fisheries. This arbitrary distinction also permits a division of localities in regard to the principal

methods of fishing. Although in all localities there exists more or less shallow-water fishing, the main quahaug industry of several towns is the deep-water fishery. In all the Buzzard's Bay towns except Fairhaven and New Bedford the shallow-water fishery prevails; this is also true of the south side of Cape Cod. On the north side of Cape Cod the opposite is true, as the quahauging at Wellfleet, Eastham, Orleans and Brewster is practically all deep water fishing. At Edgartown and Nantucket, although there is considerable shallow-water digging, the deep-water fishery is the more important.

The deep-water fishery is vastly more productive than the shallow-water industry, furnishing in 1907 118,500 bushels, compared to 23,227 bushels, or more than five times as much. The deep-water fishery, *i.e.*, the basket-rake fishery, is the main quahaug fishery of the State, and each year it is increasing, because of the opening of new beds. On the other hand, the shallow-water grounds are rapidly becoming barren from overfishing. The deep-water quahauging is harder work, requires considerable capital but has fewer working days. Naturally the earnings from this fishery should surpass those of the shallow-water industry. The deep-water quahauger averages from $5 to $8 for a working day, while the shallow-water fisherman earns only from $2 to $3 per day.

Both power and sail boats are used in deep-water quahauging, though power is gradually replacing the old method of sailing, because of its increased efficiency and saving of time. When the quahaug grounds are reached, the boat is anchored at both bow and stern, one continuous rope connecting both anchors, which are from 500 to 600 feet apart, in such a way that the bow of the boat is always headed against the tide. A sufficient amount of slack is required for the proper handling of the boat, which can be moved along this anchor "road" as on a cable, and a large territory raked. The rake is lowered from the bow of the boat, the length of the handle being regulated by the depth of the water, and the teeth worked into the sandy or muddy bottom. The quahauger then takes firm hold of the crosspiece at the end of the handle, and works the rake back to the stern of the boat, where it is hauled in and the contents dumped on the culling board or picked out of the net. In hauling in the net the rake is turned so that the opening is on top, and the mud or sand is washed out before it is taken on board. The long pole passes across the boat and extends into the water on the opposite side when the rake is hauled in. This process is repeated until the immediate locality becomes unprofitable, when the boat is shifted along the cable. The usual time for quahauging is from half ebb to half flood tide, thus avoiding the extra labor of high-water raking. Deep-water raking is especially hard labor, and six hours constitute a good day's work.

Boats. — Nearly all kinds of boats are utilized in the quahaug fishery, and are of all values, from the $10 second-hand skiff to the 38-foot power seine boat, which costs $1,500. The shallow-water industry requires but little invested capital. Dories and skiffs are the principal boats, costing from $10 to $25. Occasionally a sail or power boat may be used in this fishery. The deep-water industry requires larger and stronger boats. These are either power or sail boats, often auxiliary "cats," and their value runs anywhere from $150 to $1,500. The average price for the sail boats is $250, while the power boats are assessed at $350. At Orleans several large power

seine boats, valued at about $1,500, are used in the quahaug fishery. These seine boats are 30 to 38 feet over all, have low double cabins, and are run by 8 to 12 horse-power gasolene engines. The ordinary power boats have gasolene engines from 2 to 6 horse-power. In this way each method of quahauging has its own boats, which are adapted for its needs.

Dredging. — So far as known, dredging is never used in quahauging in Massachusetts, although it is sometimes used on sea-clam beds. It has been tried, but without success, chiefly because of the uneven nature of the bottom. The invention of a suitable dredge is necessary, and there can be little doubt that in the future, if this difficulty is overcome, dredging will be used in the quahaug fishery. In 1879 Ingersoll (8) reports in Rhode Island the use of a quahaug dredge similar in structure to our rake. Evidently this form was never especially successful, possibly because these dredges could not be dragged by sail boats.

Outfit of a Quahauger. — The implements and boats used in quahauging have already been mentioned. The outfit of the average quahauger in each fishery is here summarized: —

Deep-water Quahauging.		*Shallow-water Quahauging.*	
Boat,	$300	Boat,	$20
2 rakes,	20	Tongs or rakes,	3
3 poles,	6	Baskets,	2
	$326		$25

Season. — The quahaug fishery is essentially a summer fishery, and little if any is done during the winter. The season in Massachusetts lasts for seven months, usually starting the last of March or the first of April, and ending about the first of November. The opening of the spring season varies several weeks, owing to the severity of the weather; and the same is true of the closing of the season.

As a rule, the Buzzard's Bay industry, where digging is done in the shallow waters of protected bays and coves, using short rakes and tongs, has a longer season than the quahaug industry of Cape Cod, where the fishery is carried on in deep and open waters. With the former, the cold work and hardship alone force the quahaugers to stop fishing, a long time after storms and rough weather have brought the latter industry to an end.

The actual working days of the deep water quahauger number hardly over 100 per season, while those of the shallow-water fisherman easily outnumber 150. The deep-water quahauger's daily earnings are two or three times the daily wages of the shallow-water quahauger, but the additional number of working days in part makes up this difference.

The quahaug season can be divided arbitrarily into three parts: (1) spring; (2) summer; (3) fall. The spring season lasts from April 1 to June 15, the summer season from June 15 to September 15, and the fall season from September 15 to November 1. These seasons are marked by an increase in the number of quahaugers in the spring and fall. The men who do summer boating quahaug in the spring before the summer people arrive, and in the fall after the summer season is over. The opening of the scallop season, in towns that are fortunate enough to possess both

industries, marks the closing of the quahaug season. These two industries join so well, scalloping in the winter and quahauging in the summer, that a shellfisherman has work practically all the year.

Marketing. — The principal markets for the sale of Massachusetts quahaugs are Boston and New York. In 1879 the Boston market, according to Ingersoll (8), sold comparatively few. At the present time the Boston market disposes of many thousand bushels annually, but nevertheless the greater part of the Massachusetts quahaugs are shipped to New York. This, again, is due to the better market prices offered by that city. Besides passing through these two main channels, quahaugs are shipped direct from the coast dealers to various parts of the country, especially the middle west. This last method seems to be on the increase, and the future may see a large portion of the quahaug trade carried on by direct inland shipments.

(*a*) *Shipment.* — Quahaugs are shipped either in second-hand sugar or flour-barrels or in bushel bags. The latter method is fast gaining popularity with the quahaugers and dealers, owing to its cheapness, and is now steadily used in some localities. When quahaugs are shipped in barrels, holes are made in the bottom and sides of the barrel, to allow free circulation of air and to let the water out, while burlap is used instead of wooden heads.

(*b*) *"Culls."* — Several culls are made for the market. These vary in number in different localities and with different firms, but essentially are modifications of the three "culls" made by the quahaugers: (1) "little necks;" (2) "sharps;" (3) "blunts." The divisions made by the firm of A. D. Davis & Co. of Wellfleet are as follows: (1) "little necks," small, 1½ to 2¼ inches; large, 2¼ to 3 inches; (2) medium "sharps," 3 to 3¾ inches; (3) large "sharps," 3¾ inches up; (4) small "blunts;" (5) large "blunts."

(*c*) *Price.* — The prices received by the quahaugers are small, compared with the retail prices. "Little necks" fetch from $2.50 to $4 per bushel, sharps and small blunts from $1.10 to $2, and large blunts from 80 cents to $1.50, according to the season, fall and spring prices necessarily being higher than in summer. The price depends wholly upon the supply in the market, and varies greatly, although the "little necks" are fairly constant, as the demand for these small quahaugs is very great. To what excess the demand for "little necks" has reached can best be illustrated by a comparison between the price of $3 paid to the quahauger per bushel, and the actual price, $50, paid for the same by the consumer in the hotel restaurants.

(*d*) *Bedding Quahaugs for Market.* — By town laws in Orleans, Eastham and Wellfleet, each quahauger may, upon application, secure from the selectmen a license, giving him not more than 75 feet square of tidal flat upon which to bed his catch of quahaugs. While no positive protection is guaranteed, public opinion recognizes the right of each man to his leased area, and this alone affords sufficient protection for the success of this communal effort, which is the first step by the people toward quahaug farming.

The quahauger needs only to spread his catch on the surface, and within two tides the quahaugs will have buried themselves in the sand. Here they will remain, with no danger of moving away, as the quahaug moves but little. The quahauger loses nothing by this replanting, as not only do the quahaugs remain in a healthy condition, but even grow in their new environment.

The result of this communal attempt at quahaug culture is beneficial. While the market price for "little necks" is almost always steady, the price of the larger quahaugs fluctuates considerably, and the market often becomes "glutted." This would naturally result in a severe loss to the quahauger if he were forced to keep shipping at a low price. As it is, the fortunate quahauger who possesses such a grant merely replants his daily catch until the market prices rise to their proper level. An additional advantage is gained by the quahauger, who at the end of the season has his grant well stocked, as higher prices are then offered. As many as 1,000 barrels are often held this way at the end of the season.

History of the Fishery. — Although reckoned inferior to the soft clam (*Mya arenaria*), the quahaug was dug for home consumption for years in Massachusetts, and but little attempt was made to put it on the market. The commercial quahaug fishery started on Cape Cod, about the first of the nineteenth century, growing in extent until about 1860. From 1860 to 1890 the production remained about constant. The production in 1879 for Massachusetts, as given by A. Howard Clark, totalled 11,050 bushels, valued at $5,525. It is only in the last fifteen to twenty years that the actual development of the quahaug fishery has taken place. The present production of Massachusetts is 144,044 bushels, valued at $194,687. To the popular demand for the "little neck" can be attributed the rapid development of the quahaug industry during the last ten years. This development has furnished employment for hundreds of men, and has given the quahaug an important value as a sea food. What it will lead to is easily seen. The maximum production was passed a few years ago, constant overfishing caused by an excessive demand is destroying the natural supply, and there will in a few years be practically no commercial fishery, unless measures are taken to increase the natural supply. Quahaug farming offers the best solution at the present time, and gives promise of permanent success.

Not only has there been an increase in production, but also an increase in price, which has more than doubled between 1888 and 1902, and has alone supported a declining fishery in many towns, making it still profitable for quahaugers to keep in the business, in spite of a much smaller catch. The advance in price is due both to the natural rise in the value of food products during the past twenty-five years and also to the popular demand for the "little neck," or small quahaug.

Statistics of the Quahaug Fishery. — In the following table the towns are arranged in alphabetical order, and the list includes only those towns which now possess a commercial quahaug fishery. In giving the number of men, both transient and regular quahaugers are included. In estimating the capital invested, the boats, implements, shanties and gear of the quahauger are alone considered, and personal apparel, such as oil-skins, boots, etc., are not taken into account. The value of the production for each town is based upon what the quahaugers receive for their quahaugs, and not the price they bring in the market. The area of quahaug territory given for each town includes all ground where quahaugs are found, both thick beds and scattering quahaugs.

Town.	Number of Men.	Capital invested.	Number of Boats.	Number of Dories and Skiffs.	1907 Production.		Area in Acres.	Value of Yield per Acre.
					Bushels.	Value.		
Barnstable,	25	$850	-	25	2,500	$3,700	950	$3 95
Bourne,	46	1,000	-	46	5,400	8,400	2,500	3 36
Chatham,	50	5,750	25	25	6,700	10,000	2,000	5 00
Dennis,	15	150	-	10	500	950	200	4 75
Eastham,	25	8,000	12	-	10,000	11,500	4,000	2 87
Edgartown,	70	12,000	42	18	20,000	32,000	1,800	17 77
Fairhaven,	115	5,000	11	100	15,000	16,500	3,000	50 50
Falmouth,	-	-	-	-	100	115	400	29
Harwich,	7	200	-	7	1,500	2,550	100	25 50
Marion,	19	250	-	19	800	1,500	400	3 75
Mashpee,	7	70	-	5	250	285	400	71
Mattapoisett,	28	500	-	28	800	1,500	750	2 00
Nantucket,	48	6,750	30	10	6,294	8,487	5,290	1 60
Orleans,	75	25,000	30	25	33,000	41,350	1,500	27 56
Wareham,	50	1,000	-	50	6,000	10,500	1,300	8 08
Wellfleet,	145	27,500	100	-	33,000	41,350	2,500	16 54
Yarmouth,	20	240	-	10	2,200	4,000	1,000	4 00
Totals,	745	$94,260	250	378	144,044	$194,687	28,090	$6 93[1]

[1] Average.

The Laws.

In the past there has been a scarcity of quahaug legislation as there has been little demand for the protection of this mollusk; but within a few years the legal regulation of the quahaug fishery will become a most important part of the shellfish legislation of Massachusetts. The quahaug industry is entering upon a new phase of existence, the cultural stage, and the development of the industry along such lines will necessarily entail numerous laws governing the leasing, planting, pollution and sale of quahaugs. For this reason it may be well to consider what has already been done in a legislative way for the protection of the quahaug fishery.

Little direct quahaug legislation has been passed, as the quahaug usually has been included in general laws with other commercial shellfish. The reason for the lack of legislation is probably due to the recent growth of the quahaug fishery, which has only in the past fifteen years developed into an important industry.

Previous to 1904 the quahaug, with the clam, oyster and scallop, came in the general acts under the term shellfish. The general acts were of several kinds: (1) town regulation; (2) permits; (3) seizure in

vessels; and (4) protection of the shellfisheries by limiting the catch, place and time of taking.

In 1874 occurs the first mention of the word quahaug in a legislative act "to regulate the shellfisheries in the waters of Mount Hope Bay and its tributaries," whereby the selectmen of the towns bordering on Mount Hope Bay were permitted to grant licenses for the cultivation of clams, quahaugs, scallops and other shellfish to any inhabitant. It seems strange that such an advanced and beneficial act should have been passed at that early period, since it was clearly before its time, as is shown by its repeal the following year. It is only within the last two years that similar legislation has been passed for the quahaug, as illustrated by the act of 1909, which permits the granting of leases for the growing of quahaugs by the selectmen provided the town meeting has voted to adopt the general law. The act of 1874, although it applied only to the Narragansett Bay section of Massachusetts, brings out clearly the fact that the cultivation of shellfish is no new project as it was considered of practical importance thirty-five years ago.

In 1880 the word quahaug again appears in the general act whereby the Commonwealth gave to the towns and cities their present oversight and power "to control and regulate the taking of eels, clams, quahaugs and scallops." This act was later amended by the Acts of 1889, but the general terms were not changed, and the present law differs but slightly. As the seacoast towns hold their control over the shellfisheries as a direct trust from the Commonwealth, it is their duty to preserve the fisheries, while the Commonwealth should see that the towns take the proper care of their natural shellfish resources. Certain towns should be deprived of the rights which they are abusing in neglecting one of the great resources of the public wealth, which belongs not only to the inhabitants of the seashore communities but to *every resident* of this Commonwealth. At the present time, owing to a certain self-satisfaction and fear of outside influence, the majority of fishermen prefer the present system of town control, no matter if the shellfisheries suffer, and until public opinion is favorable for the utilization of the quahaug fishery for every inhabitant of the Commonwealth, both fishermen and consumer, State control is not desirable.

In 1900 occurred the first special quahaug legislation, in the form of an act forbidding in the towns of Swansea and Somerset the capture of quahaugs less than 1½ inches across the widest part. Since that time five other laws relating to the quahaug fishery have been enacted, in all three town and three general. The following features are illustrated by these acts: —

Limiting the Size of Quahaugs captured. — The capture of quahaugs under 1½ inches across the widest part was forbidden by law in 1900 in the towns of Swansea and Somerset, in 1901 in Berkley, in 1903 in Edgartown, and in 1904 in Eastham, Orleans and Wellfleet. This

law has also been adopted by other towns under the regulation of the selectmen, and is to be commended for the protection afforded to the home industries, as the gain for leaving the small quahaugs is many times the profits on the small seed. In this connection attention is again called to the shipment in the past of the small seed from Nantucket, Chatham and New Bedford to localities outside the State, where they are replanted, with a return, in one year's time, of about 5 bushels for every bushel planted.

Permits. — In Eastham, Orleans and Wellfleet the selectmen are empowered to issue permits for the capture of the quahaug, while in Edgartown, Berkley, Swansea and Somerset the permits are issued for shellfish in general. Often the towns are very slack about the enforcement of requiring permits, although Edgartown is to be highly commended for the excellent manner of regulating, by inspectors, her shellfish permits. These permits are given at the discretion of the selectmen, and are supposed to require six months' residence in the town. Different prices are charged for these permits: in Edgartown, $2; in Wellfleet, $1; in Berkley, although empowered by the Acts of 1901, no permits are given; in Somerset and Swansea only clam permits are given. The provisions of the Edgartown permit limit the catch to 4 bushels from sunrise to sunset, no more than 2 of which can be "little necks." The Wellfleet permits limit the daily catch to 4 barrels per man.

Bedding Quahaugs. — In Eastham, Orleans and Wellfleet the selectmen may give, for a period of not over two years, under such conditions as they may deem proper, to any inhabitant of the respective towns, licenses to bed quahaugs in any waters, flats or creeks where there is no natural quahaug bed, not covering more than 75 feet square in area, and not impairing the private rights of any person or materially obstructing any navigable waters. The object of this law was to make possible the advantage of a favorable market, as the quahauger could bed his catch until the market brightened and the price went up, otherwise he would be compelled to ship at a low figure. Undoubtedly the originators of this act did not foresee that in this way they had taken the first step toward quahaug farming, as the success of bedding quahaugs has demonstrated to the quahaugers of this section the practical benefits which would be derived from quahaug culture.

Contaminated Waters. — One of the detrimental results of civilization has been the pollution of the public waters in Massachusetts, which appears to us most unfortunate, as in the light of present-day knowledge, such a state of affairs could be readily avoided. The tendency of the past has been to dispose of sewage, manufacturing wastes and other refuse by allowing it to flow into the nearest streams. In this way some of the finest rivers in the Commonwealth, the Merrimac, Connecticut, Taunton, Charles and Mystic, have had their fisheries ruined.

Pollution has not been confined to the fresh water alone, but has for commercial purposes ruined the shellfish beds of many salt-water harbors. In several cases, particularly at Boston, Lynn and New Bedford, certain parts of the harbors have been closed by the State Board of Health in the interest of the public health.

For years the relation of the oyster from infected beds to epidemics of typhoid fever has been known and definitely traced. The same is true of the clam and quahaug, particularly the "little neck," which is consumed raw. The quahaug, when feeding, acts as a living filter, since all the microscopic forms in the water, taken through the incurrent siphon, are strained out by the cilia on the gills. Thus, if the typhoid bacilli are present in the water, as is the case when sewage from the houses of typhoid patients empties near the shellfish beds, they are collected by the feeding quahaug. The person partaking of a raw quahaug from this locality would be ingesting a concentrated collection of germs, with perhaps serious results. Cooked quahaugs are more free from germs, and if thoroughly cooked are possibly wholesome, as a certain temperature is fatal to the bacillus. Unfortunately, cooking cannot always be relied upon to reach the requisite temperature.

In 1901 it was enacted that the Commissioners on Inland Fisheries and Game (now the Commissioners on Fisheries and Game), whenever so requested in writing by the State Board of Health, should prohibit the taking of oysters, clams, scallops and quahaugs from the tidal waters or flats of any part of the Commonwealth for such period of time as the board of health might determine. The penalty for violation was, for first offence not less than $5 and not more than $10, and not less than $50 nor more than $100 for each subsequent offence. Unfortunately the beneficial effect of this law, namely, the protection of the public health by the closing of sewage-polluted areas, was rendered void by the passage of a bill in 1907 permitting the taking of shellfish from these areas for bait, upon securing permits from the board of health. Although the law provides heavy penalties for buying and selling, experience has shown the impracticability of effective enforcement on account of the ease with which (1) proofs are destroyed by the violator, and (2) the difficulty of tracing any lot of polluted shellfish to prove that their ultimate destination, perhaps a week or two hence, is human food and not fish bait. Very few quahaugs are used for bait, and the absurdity of the situation is shown when in the case of the Acushnet River over 1,100 permits to take quahaugs for bait have been issued by the New Bedford Board of Health. In such cases as the Acushnet River, where seed quahaugs are abundant, a means should be found to permit the sale of the seed for planting purposes *within the Commonwealth* by the passage of a special act for the town of Fairhaven and city of New Bedford. But until the laws permit the planting of such quahaugs it is impossible to adequately solve the question of obtaining seed from the polluted areas. Transplanted

to pure water these mollusks will readily purify themselves from all contamination.

Biological Investigation. — In 1905 the Commissioners on Fisheries and Game were empowered to make a biological investigation and report as to the best methods, conditions and localities for the propagation of quahaugs. The results of that investigation are embodied in this report.

Planting, Cultivation and Bedding of Quahaugs. — In 1909 the selectmen of towns or the mayor or aldermen of cities, provided the act is approved by the city council or by the voters of the town at an annual or special town meeting, are empowered to issue written licenses for the purpose of planting and cultivating quahaugs upon and in the flats and creeks below mean low-water mark, for a term of not more than ten and not less than five years. The important fact that up to the present time no town has taken advantage of this act, which permits practical quahaug culture being carried on, is another proof of the inability of the coast towns to properly adjust their point of view toward the practical means not only of preserving their natural supply from extinction but also of building up an extensive and profitable business for the inhabitants.

Date.	Kind.	Provisions.
1900, . .	Special town, . .	No quahaugs less than 1½ inches to be taken in Swansea and Somerset.
1901, . .	Special town, . .	No quahaugs less than 1½ inches to be taken in Berkley.
1901, . .	State, ...	No quahaugs to be taken from the waters closed by the State Board of Health.
1903, . .	Special town,	No quahaugs less than 1½ inches to be taken in Eastham, Orleans and Wellfleet. Selectmen of these towns empowered to grant permits for taking quahaugs. For bedding quahaugs, grants not exceeding 75 feet square, given on the flats and creeks.
1905, . .	State, ...	Biological investigation of quahaug fishery by the Fish and Game Commission.
1909, . .	State, ...	Planting, cultivation and bedding of quahaugs.

The Food Value.

The market value of the quahaug except in the case of "little necks" depends rather upon the quality of the meat than on the appearance of the shell. In the growth experiments the ratio of the meats to the shell, in other words, the "fattening," has been little considered. While an increase in shell naturally presupposes a corresponding increase in the soft parts, it does not always follow that the quality of the soft parts has improved. Oyster planters bed oysters to obtain rapid growth, and then transplant the stock to other waters to "fatten" for the market, because localities of rapid growth are not always suitable for fattening purposes. Naturally the ratio between shell and

meat varies in the different localities, owing to the environment, food, amount of lime in the water, etc. The prospective quahaug culturist should therefore determine not only the growing property of his grant but also the quality of the product.

Owing to the heavy shell the actual amount of food is but a small per cent. of the total weight of the quahaug. To find the ratio between the meat and shell, a series of determinations on various sized quahaugs were made in three localities, Buzzard's Bay, the Islands and the north side of Cape Cod. For this purpose quahaugs were taken from Fairhaven, Nantucket and Wellfleet. Four sizes of "sharps," 10 each, measuring 55, 65, 75 and 85 millimeters, were taken for comparative purposes in each locality. Whenever possible the weight of "blunts" of similar sizes was also recorded for comparison with the "sharps." The method of work consisted in (1) obtaining the correct sizes from the fresh catch, care being taken to select no deformed specimens; (2) the determination of the total weight; (3) the removal of the meats and fluid; (4) determination of the weight of the meats; (5) records of the natural conditions of the beds where the quahaugs were taken; (6) determination of the volume of the different parts by water displacement to serve as a check on the weighing.

Chemical Composition. — As a food the quahaug ranks next to the scallop and ahead of the oyster in proteins, carbohydrates and minerals. The following figures are from the tables of Professor Atwater, rearranged by Langworthy (15). The food value of the quahaug in the shell, removed from the shell and canned is compared with the scallop, oyster and clam.

	Refuse, Bone, Skin, etc. (Per Cent.).	Salt (Per Cent.).	Water (Per Cent.).	Protein (Per Cent.).	Fat (Per Cent.).	Carbohydrates (Per Cent.).	Mineral Matter (Per Cent.).	Total Nutrients (Per Cent.).	Food Value per Pound (Per Cent.).
Oysters, solids,	-	-	88.3	6.1	1.4	3.3	.9	11.7	235
Oysters, in shell,	83.3	-	15.4	1.1	.2	.6	.4	2.3	40
Oysters, canned,	-	-	85.3	7.4	2.1	3.9	1.3	14.7	300
Scallops,	-	-	80.3	14.7	.2	3.4	1.4	19.7	345
Soft clams, in shell,	43.6	-	48.4	4.8	.6	1.1	1.5	8.0	135
Soft clams, canned,		-	84.5	9.0	1.3	2.9	2.3	15.5	275
Quahaugs, removed from shell,	-	-	80.8	10.6	1.1	5.2	2.3	19.2	340
Quahaugs, in shell,	68.3	-	27.3	2.1	.1	1.3	.9	4.4	65
Quahaugs, canned,	-	-	83.0	10.4	.8	3.0	2.8	17.0	285
Mussels,	49.3	-	42.7	4.4	.5	2.1	1.0	8.0	140
General average of mollusks (exclusive of canned).	60.2	-	34.0	3.2	.4	1.3	.9	5.8	100

The Meat. — The entire solid contents of the quahaug is used for food, whereas with the scallop only the adductor muscle or "eye" is taken. The meat is either eaten raw, when the quahaugs are served as "little necks" on the half shell, or cooked in various ways.

With advancing age, as is shown by the increase in the weight of the meat of the "blunt" when compared with the same sized "sharp," the flesh becomes tough and of a yellow color, which renders it less edible than the tender "little neck."

Comparison by Localities. — In the following table the average quahaug of 70 millimeters (2⅘ inches) for Wellfleet on Cape Cod, Nantucket on Vineyard Sound, and Fairhaven on Buzzard's Bay is shown. The per cent. by weight of the different parts was determined by the average of the four sizes, as described above. The important factor is the per cent. by weight of the solid contents.

The average gives the value for the 70-millimeter quahaug for the State. From 100 pounds of quahaugs by weight the consumer would obtain 13.57 pounds of meat.

Locality.	Total (Per Cent.).	Shell (Per Cent.).	Solid Contents (Per Cent.).	Fluid Contents (Per Cent.).
Wellfleet, .	100	62.98	12.12	24.90
Nantucket, . . .	100	63.09	13.53	23.38
Fairhaven, .	100	61.33	15.07	23.60
Average, . . .	100	62.47	13.57	23.96

The Food Value of the Quahaug and Scallop. — In comparing the food value of the scallop and quahaug by weight it is necessary to eliminate the fluid in the shell from consideration, as it is variable with the scallop. Again, only the adductor muscle is eaten in the scallop, while the entire solid contents of the quahaug is consumed. When the weight of the shell and the edible portion are considered, it is interesting to note that the amount of edible materal in both shellfish is practically the same in per cent. by weight, being 17.85 per cent. for the quahaug, and 17.77 per cent. for the scallop. Since the weight of the quahaug's shell is 82.15 per cent. and the scallop's but 49.43 per cent., the non-edible soft parts of the scallop amount to 32.80 per cent.

Shell. — The amount of lime in the water and age of the quahaug determine the weight of the shell, although the character of the soil appears to have an indirect effect upon the nature of the lime structure. Likewise, the rate of growth is important, as the slow-growing quahaugs apparently have thicker shells than those in more favorable localities. As the size of the quahaug increases from 55 to 85 millimeters the weight of the shell in per cent. of the total weight increases .06 per cent. for each millimeter gain in length, the meats .04 per cent., while

the fluid contents decreases .1 per cent. The shell of a "blunt" weighs over one and one half times that of a "sharp" of the same size.

Unlike the scallop the quahaug is seldom put through the process of "soaking," as it is usually shipped to market in the shell. Occasionally when "shucked" the volume is increased by judicious "feeding" with fresh water. The small quahaugs are more responsive to "soaking" than the old tough specimens, but as they are generally served on the half shell this process is seldom used.

"Soaking" is accomplished by placing the quahaug meats in fresh water, thereby causing a swelling of the tissues, which increases the bulk about one-third. The principal change is attributed to osmosis, which distends the tissues. It was found that after twenty-four hours of soaking the tissues lost the water and gradually returned to their normal weight.

THE RATE OF GROWTH.

Object. — The experiments on growth were conducted with the following objects: (1) to ascertain the normal rate of growth; (2) to find the average length of life; (3) to determine the length of time necessary for the production of a marketable quahaug; (4) to discover practical methods of artificial culture and propagation in order to replenish the barren flats and to check the decline of the natural supply; (5) to obtain information of value to prospective quahaug culturists.

General Plan. — The principal results of these experiments have already been given in previous reports and this paper merely presents the work in detail showing the general method of obtaining the data. With the limited appropriation available $500 per year it was impossible to conduct the investigation in as extensive and comprehensive a manner as could have been desired. In order to obtain satisfactorily the general growth for Massachusetts and the effect of environment, such as soil, current, tide, depth of water, etc., it was necessary to have a large number of experimental plots. As means were limited, the greater part of these beds were of small size, less than 1/1000 of an acre, since it was considered advisable to plant a large number of small plots, covering a variety of conditions, rather than a few large costly beds, as small areas seem to furnish, for all practical purposes, a true index of growth in any locality. In accordance with this plan 187 small experimental beds were planted along the Massachusetts coast, and records of their growth were taken at stated intervals over a period of five years. By planting quahaugs which were five years old, as well as younger ones, at the beginning of the investigation the growth of the quahaug has been determined not only for the five years but for a much longer period. The growth experiments of Kellogg (2) were taken as a basis for this investigation, and the work carried out upon the lines indicated by that investigator. The experiments have been conducted on a practical commercial basis, as the main object was the increasing of the natural supply.

Methods of Work.

Localities. — Five places on the Massachusetts coast were chosen as representative localities: (1) the island of Nantucket; (2) Monument Beach on the shore of Buzzard's Bay; (3) Plymouth harbor, representing the northern commercial range of the quahaug; (4) Wellfleet harbor, the center of the greatest quahaug area in the Commonwealth; and (5) Monomoy Point, in the town of Chatham, as representing the south side of Cape Cod. As it seemed best to concentrate the work as much as possible, the greater part of the experiments were conducted in the last two localities, only a few beds being planted in the other three. These two places, Wellfleet and Monomoy, may be considered as fairly representative of the two great quahaug areas, — the north and south sides of Cape Cod.

Experimental Beds. — The first experimental plots were laid out in terms of the acre, 1/1000 of an acre being the usual size. The later beds were made even smaller, 1/4000 of an acre. The number of quahaugs corresponded to the size of the bed, and in most cases they were thinly planted as only in special instances was crowding necessary for experimental purposes. The planted quahaugs if they were fortunate enough to escape the raids of fishermen and summer residents, were measured annually, and the rate of growth recorded as long as the bed escaped destruction by man or nature. The beds were marked by stakes and protected by signs, which stated briefly that the enclosed plot was under control of the Commonwealth for experimental purposes, as provided by chapter 327, Acts of 1906. Less difficulty was found in protecting the quahaug experiments than similarly planted clam beds, which were often destroyed through human agency. The first beds were laid out in the form of pens, made by sinking boards in the soil so that they projected slightly above the surface. Owing to the difficulty of sinking the boards, the use of this type of bed was limited to shallow water. Later, when records of the migration of the quahaug were obtained, such precautions were found unnecessary, as the quahaug generally remains where planted.

The method of planting was extremely simple, the quahaugs being evenly distributed over the surface of the bed where, in a short time, according to the temperature of the water, they would burrow in the soil. In shallow-water beds and in special cases where greater accuracy was desired the quahaugs were buried by hand in the soil.

Owing to the impossibility of obtaining by raking all the quahaugs in beds such as above described, a factor which would make for inaccuracy, a method of planting was tried in which boxes of various sizes, filled with sand, were used with excellent results. The mollusks, placed in these boxes, could be lowered to any depth in the desired locality, in such a manner that they could readily be taken up and all the quahaugs obtained.

The beds were divided into two classes, below low-water mark and between the tide lines. Each bed was designed to illustrate a particular point in regard to conditions, favorable or unfavorable, which influence the growth of the quahaug, and for this reason different locations were tried. A record of each bed was kept, giving all facts about its natural location, records of growth, etc. By a comparison of these beds, the favorable and unfavorable conditions for quahaug culture could be ascertained. The beds were put in both good and poor places, on natural quahaug ground and on barren area, as often through the failure of a bed the cause may be discovered and a remedy suggested.

The Seed. — All sizes of quahaugs were planted in order to obtain data on the growth of the animal for a long period and to arrive at some conclusion as to the length of life. In general, the smallest obtainable were used, the usual size being 1 to 1½ inches. To satisfactorily obtain a complete record of the growth of this animal it was necessary to have quahaugs extremely small. Although "little necks" and even slightly smaller quahaugs could be procured at Edgartown, no quahaugs of small size could be obtained at the regular quahauging places in sufficient numbers for planting. This was due not so much to the lack of quahaug seed as to the impossibility of raking them in any great depth of water. This difficulty was encountered only at the start, as later the small quahaugs were caught in the spat boxes at Monomoy Point. In the fall of 1905, by a fortunate chance a place was found at Nantucket where quahaugs of extremely small size, running from 6 to 8 millimeters, could be obtained as late as November 1. The seed thus obtained furnished the nucleus for the growth experiments at Monomoy Point, and in 1906 another stock was obtained from the same place.

The following description of the locality at Nantucket where the small quahaugs were obtained in 1905 and 1906 is taken from notes made at that time :—

Coatou Point, consisting of a narrow strip of sandy beach, lies directly across the harbor from the village of Nantucket. On one side is a salt-water pond, connected with the harbor by a stream through which the tide flows into the pond. The stream has a bed of coarse sand and is protected by a sand bar at its mouth. The sand in the lower part of the stream, which extends for about 50 yards in a crooked course, is fine and clear white. Half way up there is a stretch of fine gravel and above this coarse sand. At the upper part of the stream, where it nears the pond, the sides rise abruptly in banks lined with heavy thatch, and are heavily set with the ribbed mussel (*Modiola plicatula*), while large bunches of the common mussel (*Mytilis edulis*) lie in the bed of the stream. In this part of the creek the quahaugs were abundant, and could be exposed by raking the surface of the sand. Many of these small quahaugs had a bit of green algæ attached to the beak of the shell, and were especially numerous in the clumps of mussels. Quahaugs could be obtained as large as 1¾ inches, but no larger, while the

majority were small (6 to 8 millimeters). The locality is evidently one of slow growth, judging from the appearance of the quahaugs and from the fact that no increase in growth between August and the following spring could be noticed. The method of gathering these small quahaugs was by hand and by sifting the sand through fine mesh screens, a slow process, as only 200 could be gathered per hour by one person.

In the following year, 1906, the seed under 1½ inches was obtained at Edgartown in Katama Bay. The quahaugs were raked in the usual manner with a basket rake of the Edgartown type; but instead of washing the mud and sand from the rake when it was drawn to the surface of the water, as is customary, the contents were dumped at once on the culling board, where the small quahaugs, which otherwise would have slipped through the meshes of the rake, were separated from the débris.

Another method of obtaining seed was by means of the box spat collectors on the raft at Monomoy Point. The subject of spat collecting has already been discussed, and the method of obtaining the young quahaugs described. It was possible to obtain the desired sizes, even very small specimens. In this way a study of the early life history proved advantageous for the cultural experiments, as quahaugs could be hatched for planting purposes.

Measuring the Quahaugs. — For convenience the measurements were taken in the metric system. Three methods of measuring were used: (1) rule; (2) callipers and rule; (3) triangular measuring instrument, such as pictured in the report on the "Scallop Fishery," 1910. The first two were used only for a short time at the beginning of the work and soon gave place to the third method, which proved more satisfactory in speed and accuracy. This instrument consists of an inverted triangle, formed by two strips of metal welded together at the apex of the triangle and joined at the base by a short cross-piece. The whole structure is made of brass, except the braised joint, and can be made as light as desired, although there is danger of a heavy blow rendering a light instrument inaccurate. Several sizes are used in the work, the most convenient having a base measuring 3 inches. The sides of the triangle are scaled in the metric system on one face and in fractions of inches on the other, the divisions corresponding to the millimeter markings on the ordinary rule, being about 5 millimeters apart, thus enabling the operator to make easier and more accurate readings. When measuring, the triangle is held with the base away from the body, and the object is brought down the narrowing sides until it strikes, at which point the measurement is read.

Three measurements were made of each quahaug, *length,* along the anterior posterior axis; *width,* from the umbones to the edge of the shell, along the dorso-ventral axis; and *thickness,* from valve surface to valve surface, along the lateral axis. After a sufficient number of

measurements were taken, a table was formulated by which the corresponding width and thickness for any given length might be calculated. The use of this table eliminated the necessity of taking more than the length measurements.

An easy method of recording the growth of the planted quahaugs consisted in notching the edges of the shell with a file. The mark thus made would remain permanently on the shell, showing the increase in growth. This efficient method was originally used by Dr. A. D. Mead of the Rhode Island Commission of Inland Fisheries in his experiments on the soft clam (*Mya*), and has proved very satisfactory in our quahaug experiments. It has been used not only as a check upon other measurements, but, in connection with the table of length and width, has provided a permanent record for successive yearly growths.

The simple statement of the gain in length does not adequately express the actual increase in the bulk of the quahaug, which should be indicated in terms of volume. A quahaug which grew in one year from a length of 1 inch to a length of 2 inches, a gain of 1 inch, does more than merely double in size, as the figures would seem to indicate. When the gain in volume is considered by comparing the water displacement of the two sizes, it is found that the volume of the 2-inch quahaug is over seven times that of the 1-inch, which gives the true increase. The quahaug shuts its shell closely enough to be water tight, and it is relatively an easy matter to accurately obtain its water displacement, a process impossible with the soft clam and scallop, which have more or less open shells. A table (see Table 3) of volume by water displacement and number per quart was made for each length from 1 to 88 millimeters, several hundred specimens being used for each size, except for the sizes under 6 millimeters. The individual quahaugs vary greatly, some being thick, others thin, some narrow, others wide. For this reason it was necessary to use a large number of quahaugs of each size, and after plotting the results on co-ordinate paper to form a uniform curve for the volume.

Monomoy Experiments.

During the period from 1905 to 1910 growth experiments were conducted in the Powder Hole, a sheltered harbor of salt water situated at Monomoy Point, Chatham, at the elbow of Cape Cod. In former years the Powder Hole was a spacious harbor where a hundred vessels could anchor, but the sand bars have so shifted that at the present time nothing remains but an almost enclosed body of water, of perhaps 3 acres, connected with the ocean on the bay side by a narrow opening through which a dory may enter at high tide. The opening changes constantly, owing to the shifting nature of the sand, and has successively worked from the south to the north side, closed and re-opened again at the south at intervals of one and a half years. A large part of the original harbor is now either dry land or salt marsh, while on

the north and west side is a sand flat of 3 acres, which up to 1910 contained an abundant quantity of soft clams. The harbor itself is slowly diminishing in size, due to the encroachment of the sand, and will doubtless eventually become a small pond, not connected with the ocean. By referring to Fig. 31 the location of the flats and experiments can be seen.

The water on the north and west sides averaged from 15 to 18 feet in depth, gradually shoaling to the south and east. In the shallow water the soil was covered with an abundant growth of eelgrass. The rise and fall of the tide was about 1½ feet on the average, but extremely erratic, as the force and direction of the wind and the position of the opening were important in determining the amount of water passing through the narrow inlet. The location and depth of the opening made it possible for the clam flat to be constantly under water for weeks, while at other times several days might pass with the water barely covering the flats. At such times the water was over the flats for only a brief period, probably not averaging much over five hours out of the twenty-four. Naturally, the amount and frequency of the tidal flow affected the salinity of the water, which varied somewhat with the influx of the tide. The amount also varied with the high or low running tides, as a certain height had to be reached before water would flow through the inlet.

The Powder Hole, which was taken by the Commonwealth for experimental lobster hatching, proved an excellent locality for experiments on the life and growth of the quahaug, as it was a natural breeding ground. In addition to the quahaugs naturally bedded in this body of water, additional seed was planted for experimental purposes. A small laboratory was erected on the shore, and a raft 20 feet long by 10 feet wide (see report on the "Scallop Fishery," 1910) was securely moored in the deepest part of the harbor.

Box Experiments. — Two main classes of experiments were undertaken, (1) bed and (2) box, which differ only slightly, the box form being a more convenient modification of the experimental bed previously described. This form consisted of small grocery boxes filled with sand and supplied with rope handles, by which they could be let down in any depth of water, either suspended from the raft or placed on the bottom in any part of the Powder Hole, where they could be raised by a line or a long hooked pole whenever desired. The advantage of the experimental box over the bed lay first, in greater accuracy, as it permitted the operator to obtain each time the same number of quahaugs that he planted, a thing that it is almost impossible to do in a planted bed, where the quahaugs must be raked under water; secondly, it furnished a convenient means of handling; and thirdly, it permitted the planting of numerous small beds, equally as efficient from a practical standpoint, under a variety of natural conditions in the different parts of the Powder Hole.

The box experiments were divided into four classes: (*a*) rack boxes placed on posts; (*b*) boxes in the shallow water near the shore, at a depth of from 1 to 5 feet; (*c*) boxes in deep water, 10 to 18 feet; and (*d*) boxes suspended by ropes from the raft. In all cases, especially on the raft, the boxes were made as strong as possible to withstand the strain of lowering and taking up. The boxes could be used only one year, as the ship worms (Teredo) render the wood unfit for service.

The method of planting a box experiment is comparatively simple. Rope handles are stretched diagonally from end to end, the number of the experiment carved on the side of the box, and the box filled one-half to two-thirds full of clean sand from the shore. The dimensions of the box and the height of the sides above the sand are recorded. The quahaugs, which have previously been measured and notched by a file on the edge of the shell, are either placed on the surface of the sand and allowed to burrow when the box is under the water, or are placed in their natural position under the sand. The box is then lowered at the desired locality.

(1) *Rack Boxes.* — This group comprises the first box experiments, which were started in October, 1905, and continued until October, 1908. These experiments have been grouped together as they comprise all the box experiments of 1905. During the first ten months these boxes were not on the raft, but were located in a different part of the Powder Hole, under circumstances which will be briefly described as follows: —

Wooden boxes of the same length and as nearly as possible the same size were arranged so as to slide between two upright posts about 8 feet long driven firmly in the bottom in from 5 to 6 feet of water. At intervals on the posts were wooden pins, so adjusted that they could be withdrawn at will. These pins furnished a resting place and support for the boxes. Thus the boxes could be raised or lowered for examination at any time. The posts were driven down so that the tops were from 1½ to 2 feet below the surface of the water at low tide, to prevent their being carried away by the ice. To the ends of the boxes were attached galvanized iron handles 3 by 4 inches, which, passing over the posts, made the runners for the boxes. Considerable difficulty was encountered in putting down the posts in getting them the right distance apart, so the boxes would slide easily. One box was used to set the posts and the others lowered after the posts were in position. The boxes were placed in sets of two and three, the former being found more advantageous.

The natural conditions of the quahaugs which were planted in these boxes were especially favorable. The location was in the northeast end of the Powder Hole, as is shown in Fig. 31, at the edge of the deep water, or where the old channel once existed. The bottom was mud covered with thin eelgrass, while the depth of the water at low tide

averaged 5½ feet. The sand in the boxes was taken from the exposed flats of the Powder Hole, and was coarse and firm. Raised as they were from the bottom at various heights, the quahaugs were entirely free from the influence of the dead eelgrass, and were able to get a better circulation of water than if resting on the bottom. The sand in the different boxes did not extend flush with the top, but varied from 1½ to 5 inches from the top of the box, leaving a projecting rim. When taken up the sand in the boxes had a muddy appearance at the surface, due to the settling of matter floating on the water. The depth of water over the boxes varied with their location, since all the racks were below low-water mark, and were never exposed. No means were at hand for obtaining the exact rate of current over these experiments, but the circulation was good, and while perhaps not as swift as at the raft was all that could be desired by the quahaug planter. The density varied with the influx of the tide from 1.021 to 1.025.

(2) *Shallow-water Boxes.* — The boxes were somewhat larger than the deep-water boxes, as they could be more easily handled. These boxes were located principally on the south and east sides of the Powder Hole, both on clear bottom and in eelgrass. It is interesting to note that the rate of growth in the boxes was more rapid than for quahaugs in the natural soil in the same locality.

(3) *Deep-water Boxes.* — These boxes were of small size, for convenience in raising. Two methods of raising them were tried. Where the water was sufficiently shallow to permit the box being seen, the pole with hook was used. In the deeper water a rope and small wooden buoy were attached to the box.

(4) *Raft Boxes.* — A raft, 20 feet long by 10 wide, was moored in the Powder Hole near the flat on the north side, where the deepest water and best circulation were obtained. It was provided with a central well and four trap-doors, by means of which the boxes could be lowered to any depth up to 18 feet. The raft was used only during the summer months, and was hauled on land for the winter, the box experiments being transferred for winter to water deep enough to escape the ice. During the winter of 1906 to 1907 a heavy rope frame on posts was placed under the water at a depth of 2½ feet from the surface. On this framework, primarily intended for wire scallop cages, were suspended a number of quahaug boxes, while others were placed on the ground in the same locality at a depth of 11 feet.

The natural conditions on the raft were especially favorable for quahaug growth, and extremely good results were obtained. The position of the raft was such as to receive the full benefit of the incoming tide as it passed through the opening over the flat, bringing with it the abundant diatomous food accumulated on the sand. In this way the circulation of the water in the vicinity of the raft was the best in the Powder Hole, and accounts for the better growth in the raft boxes.

In addition to the box experiments, quahaugs were also placed in

wire cages or baskets, and their growth obtained out of the sand. These cages were made of various sized wire mesh, from $1/4$ to $1 1/4$ inch, according to the size of the quahaugs, and usually measured $1 1/2$ by 1 by $1/2$ feet. They were suspended from the raft in the same manner as the boxes. For the very small quahaugs a series of jars were suspended, a few quahaugs in each jar.

Experimental Beds. — The experimental beds can be divided into two classes, (1) between the tide lines, (2) below low-water mark. The tidal beds were located in the different parts of the clam flat in connection with clam experiments (Fig. 31). The first of these beds was put out in October, 1905, and the last taken up in 1910. The main results are shown by the comparison of growth between the tide lines only one-fifth of the time under water and on the raft under nearly the same conditions. The first of these beds were in the form of pens made by sinking boards into the sand, but the later ones were planted without bounds of any sort, as it was found that the quahaugs did not travel far.

The beds below low-water mark were mostly confined to the east and south side of the Powder Hole, in shallow water from 2 to 4 feet deep, both in clear spaces and on eelgrass bottom. The entire number, six, planted in 1905 and 1906, were in the form of pens, and varied in size from $1/1000$ to $1/100$ of an acre. In all these beds the rate of growth was slow.

The growth experiments at Monomoy, as already shown, were grouped into the raft and bed classes. The two kinds of experimental beds, between the tide lines and below low-water mark, were continued from 1905 to 1910. The raft experiments, however, were separated into two series, the first during the four years from 1905 to 1908, when the main laboratory was at Monomoy Point, and the second during 1909 and 1910. The object of the first series was to determine the average rate of growth and methods of planting; the second, the growth of old quahaugs and blunts.

Plymouth Experiments.

Three beds of quahaugs, Nos. 118, 186 and 187, were planted on the flats of Plymouth harbor in connection with experiments on the soft clam (*Mya arenaria*). The experimental beds, situated between the tide lines, were located on Grey's and Egobert's flats in the town of Kingston, on the western side of the harbor. Plymouth harbor presents a vast area of flats more or less covered with eelgrass, with a great variety of soils. Three towns, Duxbury, Kingston and Plymouth, share the fishing rights of this harbor. The general and natural conditions are: (1) large rise and fall of tide; (2) good circulation of water, due to the swift currents, except on the shore flats of the western side; (3) high flats with long exposure; (4) variety of soils from a shifting sand to a soft mud; (5) great area of eelgrass flats.

Egobert's, the larger of the two Kingston flats, has an area of about 275 acres, covered by thick eelgrass except for a triangular piece on the mid-southern section, which comprises about 80 acres of smooth, unshifting sand. The greater part of this section is barren, although a few clams are scattered along the edge near the channel. Grey's flat, situated to the west of Egobert's, is of an entirely different type. It is a long flat, with a uniform width of 100 yards. It runs throughout its length parallel to the shore, while on the east side it is separated from Egobert's by a 300-foot channel. Like Egobert's, it is covered for the most part by eelgrass, but is essentially different in the nature of its soil which is mud throughout. Although the total area of the flat is about 115 acres, an irregular section of mud on the southeastern section, comprising 30 acres, is the only available clam territory. This area is composed of soft mud on the north and the south, but the middle section contains several acres of hard mud. Bed No. 118 was planted on the southwest side of Grey's, in the soft mud; the other two on Egobert's, — No. 187 in the eelgrass, No. 186 on the clear sand, with seed obtained at Marion.

The results, as will be seen by reference to the general table, were briefly as follows: on Egobert's the bed in the eelgrass showed a slower growth than the bed on the bare sand, due to difference in circulation of water. The averages for Grey's and Egobert's flats were about the same, showing that, where the current is the same, the soil, whether soft mud or hard sand, makes little difference in the growth of the quahaug. Growth between the tide lines, with a good circulation of water, even when the feeding period is limited to ten hours out of the twenty-four, is often better than in beds constantly under water, where there is less circulation of water. Culture on these flats is advisable only through the summer months, a gain of 2.4 bushels for every bushel of inch quahaugs planted being recorded for these two flats, as the planter runs the risk of losing his quahaugs in a severe winter. There are places where quahaugs could be safely bedded in deeper water in Plymouth harbor and Duxbury Bay, and there is reason to look forward to a combination of quahaug and clam culture on these flats. Along the western shore of the harbor the growth would be so slow as to render any culture on those shore flats impracticable, but in other parts of the harbor growth may be faster. As the growth is accomplished only during the summer months, the planter should buy large seed in the spring and sell the "little necks" in the fall, thereby not risking a winter loss.

Wellfleet Experiments.

The harbor of Wellfleet Bay, some 4 miles long and nearly 2 miles wide, contains approximately 2,500 acres of quahauging ground. The greater part of this territory is under water, ranging from a few feet in depth to upwards of 5 fathoms at low tide. Particularly in the

channel, where the water is deepest, quahaugs flourish in the greatest abundance. As the mean rise and fall of the tide is 10¾ feet, the currents flow with great swiftness, both on the ebb and flow of the tide. This may well be considered the natural home of the quahaug, as Wellfleet is the foremost town in the State in the production of this shellfish. Consequently, it seemed particularly fitting that this place should be made the scene of investigations of this nature.

The experiments were conducted during the summer of 1908, from the last of June till the first of December. All the beds in this harbor were planted between the tide lines. It was impossible to conduct experiments under water, as was done at Monomoy, owing to the fact that the tides and currents were so strong at Wellfleet as to make any raft experiments practically out of the question. Furthermore, the large fleet of quahaug boats which was engaged in the industry at this place constantly fished over the whole territory, and might have interfered with such experiments.

The beds were divided into two general divisions: (1) beds planted on staked areas in the sand or mud; (2) beds planted in boxes. The total number of the planted beds was 146, but only 84 were taken up. They were distributed along the coast from a point south of Smalley's bar on the west to a point south of Lieutenant's Island, near the Eastham line, on the east.

The size of these beds was small, usually not over 3 or 4 square feet. The main reason for this was the fact that the large territory to be studied necessitated the planting of a great number of beds, which could not, therefore, owing to our limited time, be of large size. Our custom was to drive a stake a foot long, more or less, firmly into the soil for about half its length at each corner of the bed. In addition we placed a sign beside the bed, describing the experiment as one conducted by the State. In the area enclosed by these stakes 50 quahaugs, averaging 25 millimeters in size, which had originally been obtained from the region known locally as Stony Bar, just south of Jeremy's Point, were planted by hand. These quahaugs were filed on the edge of the shell and accurately measured, so that the increase in length could be readily ascertained when they were taken up in the fall. When these beds were examined after an interval of several months the quahaugs were dug out of the sand with an ordinary clam hoe, their lengths measured, their new edges refiled, and on each the distance from the old to the new file marks accurately taken. This distance registered the increase in width, from which, by means of tables, we could easily compute the increase in length. They were then replanted in the same manner as at first, for comparison at some future date.

The 146 beds fall readily into ten divisions which are fairly well defined and easily separable. These divisions, beginning at the southwesternmost point in the harbor and extending around the circuit of the coast, are, taking them in order, as follows: (1) Smalley's bar,

(2) the Meadows, (3) Sow Rock bar, (4) Herring River, (5) Egg Island, (6) Indian Neck, (7) the north shore of Blackfish Creek, (8) the south shore of Blackfish Creek, (9) the west shore of Lieutenant's Island, (10) the south shore of Lieutenant's Island, and the neighboring region to the Eastham line.

Results.

General Growth. — The shell of the quahaug is taken as the standard in recording growth, as any increase in the soft parts causes a proportional enlargement of the shell. Of course, this does not take into account the quality of the meat, so important to the dealer, but no investigation along this line has been practicable at the present time.

The rate of growth of the quahaug is largely determined by its environment. While this accounts for much of the variation, it is true that individual differences do occur in the same bed under identical conditions, thus indicating that power of assimilation and growth varies with the individual. As a rule, the growth in any bed is fairly uniform, especially when large numbers are planted. The quahaug differs from the higher animals, in that its growth appears to be directly proportional to the amount of food consumed. Curiously enough its automatic feeding apparatus is constantly at work whenever the animal is taking water through its extended siphons, thus causing an almost constant feeding. The food consists of microscopic plant forms, called diatoms, which are distributed through the water. Naturally, the abundance of diatoms in any locality and the circulation of water are the two principal factors in growth.

Growth of the Young. — The growth of the young quahaug from the time of set or attachment was observed only at Monomoy Point, in the raft spat boxes. Here the small quahaugs were followed during the summers of 1906, 1907 and 1908, until the boxes were taken up in October and November. In 1908 the young quahaugs were visible to the naked eye as early as July 24, but in 1906 and 1907 they were not noticed until the second week in August. Contrary to expectations the small quahaugs in the spat boxes showed a slower growth than larger quahaugs under the same conditions. The average size of 276 quahaugs taken from these boxes by December 1 was only 4.9 millimeters, which seemed rather a slight five months' growth. The general average was probably lowered by the late set of certain quahaugs, since a few of the early set, when suspended from the raft in jars, showed an average gain of 3.4 millimeters per month, which would give a 9-millimeter quahaug on December 1. From these figures the arbitrary length of 5 millimeters has been adopted as the average size of the six-month quahaug on January 1.

The form of the young quahaug from the time of set is practically that of the adult. The only important difference is found in the prominent raised ridges, which readily enable the observer to distinguish

the young from other small mollusks of similar shape. On a 1-millimeter quahaug as many as 12 of these ridges could be counted (Fig. 28). As the quahaug grows these ridges appear at regular periods, evidently intervals of time rather than growth, and, as the animal grows older, gradually disappear.

Growth of Old and Young. — As can be seen from Table 2, the actual increase in length as well as the relative increase in volume constantly diminishes as the quahaug increases in size. In other words, the older and larger a quahaug becomes the more slowly it grows. By placing a series of quahaugs from 1 to 95 millimeters in boxes suspended from the raft under similar conditions as regards sand, depth and current, sufficient data were obtained to plot a curve of the year's growth and formulate a table for each sized quahaug from 1 to 100 millimeters. It was found from this experiment that a 14-millimeter quahaug evidenced the greatest gain in length, and that above this size the yearly growth for the larger quahaugs steadily diminished with advancing age. When a 14-millimeter quahaug showed a yearly gain of 27.7 millimeters, a 20-millimeter would give 25.2 millimeters; a 30-millimeter, 20.8 millimeters; a 40-millimeter, 17 millimeters; a 50-millimeter, 13.9 millimeters; a 60-millimeter, 11 millimeters; a 70-millimeter, 8.1 millimeters; an 80-millimeter, 5.1 millimeters; a 90-millimeter, 2.5 millimeters; a 100-millimeter, .6 millimeters. After the quahaug reaches a certain age or size the gain in thickness of the shell surpasses that of increasing length and width, with the result that the old quahaug becomes what is known by the fishermen as a blunt.

Blunts. — Quahaugs with shells thickened at the edges or lips, a sort of retrogressive growth typical of old age, are often taken from the fishing grounds. The size alone does not always indicate the age, as the conditions of its environment may be such as to cause a small-sized quahaug to become a blunt. In many respects slow growth is similar to old age, and may cause a thickening of the edges. Retrogressive growth occurs by a gain in thickness of the shell without a corresponding advance at the edge. Evidently the soft parts of the animal have attained their full development, and therefore the mantle cannot secrete new material for the extension of the shell.

Our experiments did not substantiate the statement of many quahaugers that blunt quahaugs, when placed in a favorable condition will become sharps, *i.e.,* attain once more a thin lip. Blunts of various thicknesses and sizes were obtained at Wellfleet and placed in the raft boxes at Monomoy Point, where conditions were favorable for rapid growth. Control experiments of small quahaugs were conducted at the same time. Part of the same lot of quahaugs were planted near the shore, where the conditions were less favorable for rapid growth. The experiments lasted from May 17 to Sept. 14, 1909. The results were briefly as follows: in the raft boxes, five classes were arbitrarily made, the first two irrespective of length and width, the last three of thickness

of lips. (1) Thick blunts; (2) thin blunts; (3) large blunts, 3¾ inches; (4) medium-sized, about 3 inches; (5) small, 2¾ inches.

(1) The thick blunts were divided between three boxes, containing, respectively, (*a*) broad blunts with ridge in center of edge; (*b*) square-edged blunts; (*c*) round-edged blunts. Box (*a*) showed an increase of 1.8 millimeters in width, as compared with a thickening of 3.22 millimeters, giving a ratio of 1.8 millimeters to 3.22 millimeters; box (*b*) 1.3 millimeters to 2.15 millimeters; and box (*c*) 1.5 millimeters to 2.35 millimeters, making an average ratio of 1.53 millimeters to 2.57 millimeters. None of the three boxes showed any definite indication of sharpening, although box (*b*) showed a thin raised edge of growth.

(2) The box of thin-lipped blunts showed a true blunting tendency, giving a typical rounded growth at the edge. These showed an increase in width of 1.6 millimeters, compared with a thickening of 4 millimeters.

(3) The large blunts were placed in three boxes, in classes of wide, medium and fine edges. The average of the three boxes gave a ratio of .7 millimeters to 2.55 millimeters, showing a slower growth for the large than the small and medium sized blunts. The large blunts with the thick lips showed the slowest gain.

(4) Two boxes of medium-sized blunts showed a ratio of 2.51 millimeters to 4.94 millimeters, one box showing a fairly good ring of growth, which might be considered an attempt at sharpening.

(5) The two boxes of small blunts showed a ratio of 1.7 millimeters to 3.6 millimeters, indicating that the shell thickened twice as fast as they increased in size.

The results in the shore experiments were as follows: the blunts placed under poor-growing conditions showed even slower growth, a gain of .22 millimeter in width, than on the raft boxes, and a correspondingly greater thickening. Also, the large blunts showed a slower growth than the small. Experiments were also tried in the opposite direction, *i.e.*, growing blunts from sharps. The sharps over 3 inches showed little gain and great thickening tendencies, but did not evidence any decided blunting. Twelve boxes were used on the raft and in the shore beds, the small sharps giving greater gain than the large.

Length of Life. — Owing to the impracticability of carrying on work for a sufficient period to determine the length of life of any particular set of quahaugs, any statements regarding the period of existence must necessarily be more or less of an estimate. Nevertheless, by means of Table 2 it is possible to give approximately close figures for the age of any given quahaug up to 4 inches in length. On the raft boxes at Monomoy Point, a very favorable place for growth, the following figures were obtained, starting with a 5-millimeter (⅕ inch) quahaug on January 1 at the age of six months. The size of 51.9 millimeters (slightly over 2 inches) was obtained in two and one-half years; 74.25 millimeters (slightly less than 3 inches) in four and one-

half years; 89.5 millimeters (slightly over 3½ inches) in seven and one-half years; 96 millimeters (slightly over 3¾ inches) in ten and one-half years; and 101.3 millimeters (about 4 inches) in sixteen and one-half years. The growth during the last six years is more or less a matter of conjecture, but up to the tenth year is approximately correct. In this case the quahaug was under favorable growing conditions. There are places where the growth is four times as slow as in the raft boxes, which would place the age of a large quahaug over fifty years. Where the growth was slow, the quahaugs would probably show blunting before they reached the size of 4 inches. Blunts are older than sharps, and their age is still more a matter of guess work, a decided blunt ranging from twenty-five years to an indefinite age.

The Little Neck. — The culturist who desires to raise the most profitable shellfish will inquire the length of time necessary for producing a marketable quahaug. The following answer, while general, will not apply in every case, since the rate of growth varies according to current, tide and other conditions of environment. In favorable surroundings the quahaug will reach a size of 2 inches in two and one-half years after birth, and at the same rate of growth will attain over 2½ inches in three and one-half years. In exceptionally favorable situations the size of 2¼ inches may be obtained in two and one-half years, and that of 2¾ inches in three and one-half years; but such rapid growth is seldom found, and more often is less than that indicated by the first set of figures. In one of the unfavorably situated experiments, where thick eelgrass cut off the circulation of water, it would have taken four times as long to produce the same size quahaug.

The Growing Months. — The quahaug, like the scallop (*Pecten irradians*), increases in size only during the summer months, no shell formation taking place during the cold weather. Its annual life consists of a period of active growth in the summer and a period of winter rest, during which the animal lies practically dormant. As with the scallop, growth begins about May 1, when the temperature of the water has reached 49° F., varying with the seasonal changes of the different years, and ceases during November, when the temperature has fallen below 45°. For all practical purposes growth ceases about November 1, at a temperature of 49°, which is especially true of the exposed Wellfleet flats, but at Monomoy Point there is a slight November growth. The decrease in the microscopic food forms (diatoms) in the water about December 1 is not sufficient to explain the cessation of growth, which is due rather to the inactivity or sluggishness of the quahaug during the cold weather. By monthly measurements of the quahaugs in the raft boxes and in the shore beds at Monomoy Point, the comparative value of the different summer months was determined in terms of the gain per cent. as follows: considering the entire year as 100 per cent., May received 3.78 per cent.; June, 10.81 per cent.;

July, 19.02 per cent.; August, 25.56 per cent.; September, 26.24 per cent.; October, 12.85 per cent., and November, 1.74 per cent.

Growth on Barren Flats. — There are few areas, no matter how adverse the natural conditions, where quahaugs will not live, but their rate of growth will depend entirely upon the environment. There are many barren flats on which they will grow, if planted, but on which certain conditions prevent the natural set. In the future it will be possible to utilize such areas for quahaug culture and to make productive localities now practically worthless.

Comparison of Localities. — The growth experiments were conducted chiefly at Wellfleet and Monomoy Point, a few beds being planted at Plymouth, Nantucket and Monument Beach. Adult quahaugs were planted for spawning purposes in the Essex and Ipswich rivers, but no record of their growth was taken. These quahaugs, one year after planting, were in a thriving condition, but showed no evidence of propagation. Nevertheless, under the prevailing conditions of rapid growth in these rivers, in spite of the inability to obtain a natural set, it should pay to plant quahaugs. The following table gives a comparison of the growth in the various localities. From a practical standpoint only the Monomoy and Wellfleet comparisons are of interest, as the other beds are too few in number.

	Nantucket.	Plymouth.	Monument Beach.	Wellfleet.		Monomoy.			
				Beds.	Boxes.	Raft Boxes.	Shore Boxes.	Shore Beds.	Flat Beds.
Number of beds,	1	3	1	80	4	48	32	6	3
Annual growth,	8.48	9.41	10.15	9.69	28.62	24.02	12.60	11.16	7.63
Increase in volume (per cent.),	132	149	163	155	783	574	216	183	117

The Monomoy experiments afforded a comparison for the four years 1906 to 1910 in the raft boxes and in the shore beds. On the raft the standard growth was as follows: in 1906, 22.84 millimeters; in 1907, 24.21 millimeters; in 1908, 18.72 millimeters; in 1909, 24.92 millimeters. In the shore beds the growth was 5.06 millimeters in 1906; 13.27 millimeters in 1907; 10.01 millimeters in 1908, and 17.43 millimeters in 1909. The slow growth for the shore beds in 1906 is partly due to the effects of transplanting, in 1908 to the closure of the outlet, which for several months interfered with the circulation in the Powder Hole.

A comparison of the various parts of the Powder Hole gives the following figures for the average growth: raft boxes, 24.02 millimeters; edge of clam flat near raft, 19.38 millimeters; clam flat, 7.63 millimeters; eastern part, 17.53 millimeters; east side, 8.92 millimeters; south side, 12.15 millimeters.

Natural Conditions.

There is no more convincing illustration of the influence of environment upon the life of the quahaug than the effect of the surrounding conditions upon its growth. Chief among these natural agents may be enumerated current, tide, soil, depth and salinity of the water, arranged in order of individual importance, yet so closely interwoven that their separate actions cannot always be clearly demonstrated. Their various combinations form a favorable or unfavorable environment for the growth of the quahaug, and govern largely the rapidity of its development. A discussion of these conditions involves their separate treatment, but the reader should realize that there are few, if any, instances where the pure uncomplicated action of a single natural condition can be obtained.

Current. — The most essential condition for shellfish growth is a good current, not necessarily an exceedingly swift flow, but rather a fair circulation of water. Current performs a threefold service: (1) it determines the supply of food for the body and lime for the shell; (2) it governs the supply of oxygen for the gills; and (3) finally, it acts as a sanitary agent.

(1) The food of the quahaug, as already stated, consists of microscopic forms, chiefly diatoms, in the water. The growth of the quahaug, as with lower animals, is directly proportional to the amount of food, and the animal situated in a current naturally receives a greater supply than one in still water. For all practical purposes current means food, and, within limits, increase in current indicates increase in the amount of food, thus furnishing an index of the growth. The amount consumed likewise depends upon the quantity in the water, the feeding power or capacity of the quahaug, and the absence of silt or other material in the water, which would interfere with the mechanical feeding process of the animal. In a similar way, current aids shell formation by increasing the supply of available lime salts.

(2) Intimately associated with its value as a food carrier is the no less important service of affording a good supply of oxygen. The quahaug, like man, needs a definite amount of oxygen to perform the normal functions of life, — to transform food into body tissues and energy. Current supplies fresh oxygen, and a quahaug with a good circulation of water is able to assimilate more food and grow faster than one in the still water.

(3) The work of sanitary agent is performed by carrying away all products of decomposition, thus preventing contamination in thickly planted beds.

From the standpoint of the culturist, circulation of water is most important, and in choosing a grant selection should be based upon the current. Nearly all our growth experiments, directly or indirectly, indi-

cate its value. A few cases are cited to show the direct experimental relation between current and growth.

A comparison of the growth in sand boxes at Monomoy Point was made in three parts of the Powder Hole: (*a*) the raft, which had a good circulation, gave an annual gain of 24.5 millimeters (612 per cent. gain in volume); (*b*) the south side, in front of the laboratory, where there was only a slight flow of water with the rise and fall of the tide, gave a gain of 16.18 millimeters (305 per cent. gain in volume); (*c*) the east side, where eelgrass cut off practically all circulation, showed a gain of 13.62 millimeters (241 per cent. gain in volume).

Wire mosquito netting was placed over part of the jars in which small quahaugs were suspended from the raft. A month later the quahaugs in the jars without netting showed a gain of 3.4 millimeters, compared with 1.21 millimeters for the netting jars, illustrating the effect on growth by restricting the circulation.

The channel connecting the Powder Hole and the ocean became blocked during the summer of 1908, with the result that there was a stagnation of water in the Powder Hole during part of the growing months. The shore beds showed a slow growth of 10.01 millimeters in 1908, as compared with 13.27 millimeters in 1907 and 17.43 millimeters in 1909.

In our experiments in Wellfleet Bay the greatest growth occurred in Herring River, Blackfish Creek and on Egg Island, which get both the backward and forward sweep of the tide. The various local groups of beds are here arranged in order of rapidity of growth: —

	Per Cent.		Per Cent.
Herring River,	100	West of Lieutenant's Island,	52
Egg Island,	75	Blackfish Creek (north side),	51
Blackfish Creek (south side),	72	Sow Rock bar,	33
Indian Neck,	68	South of Lieutenant's Island,	15
The Meadows,	55	East side of Great Island,	9

Tide. — Quahaugs are found between the tide lines, but in less abundance than beneath low-water mark, their natural habitat. This circumstance may be the result of exposure to severe winters, since the quahaug lies near the surface of the soil and not at a depth, as the soft clam. The principal effect of exposure, as demonstrated by experimental beds between the tide lines at Plymouth and Wellfleet, is the retardation in growth from loss of feeding time. The quahaug can feed only when covered with water, and exposure from four to twelve hours daily materially lessens the amount of food consumed, assuming that the quahaug feeds continually when under water. Experiments have demonstrated that the longer the exposure, the slower the

growth. Eighty experimental beds between the tide lines at Wellfleet were classified as low, medium and high, according to the length of exposure (Fig. 36). The low beds, 32 in number, having a better circulation and longer feeding period, gave an annual growth of 12.5 millimeters (.49 of an inch); the 27 medium gave 7.82 millimeters (.31 of an inch); and the 21 high beds showed a gain of 7.17 millimeters (.28 of an inch). Considering the growth of the low beds as 100 per cent., the medium would show 61.53 per cent. and the high 57.39 per cent. While this evidence is open to the criticism that the faster growth of the low beds was due to a better circulation of water, it is confirmed by an experiment at Monomoy Point, where the annual growth was 24.02 millimeters in the raft boxes, as compared with 7.63 millimeters on the near-by clam flat under the same conditions, except for the exposure of the flat.

Planting between the tide lines entails considerable loss. Only 84 out of 154 beds were recovered at Wellfleet, over 50 of the remaining 70 having been washed away, buried or destroyed by cockles, the greatest loss occurring in the exposed portions of the bay, especially near Lieutenant's Island. After three months only 42 per cent. of the planted quahaugs were found in the 84 good beds. Life between the tide lines is a difficult existence for the quahaug, especially for the smaller animal, which is forced to maintain a continual struggle against adverse conditions.

Depth. — The depth of water over the grant is of practical interest to the culturist, who desires rapid growth and at the same time easy facilities for harvesting. Owing to the better circulation of water, the average growth in the deep water will exceed that in the shallow; but in localities where the current is approximately the same, any depth beyond 3 feet at low tide (for protection during the winter) gives no increased growth and affords a distinct disadvantage to the planter in taking up his crop. The quahaug appears to live equally well at any depth, and is occasionally raked in 50 feet of water on the north side of Cape Cod.

The relation of depth to growth could not be experimentally determined on a large scale owing to the cost and difficulty of planting in deep water. A few observations regarding the rate of growth at various depths were made from the raft at Monomoy Point, but these apply more to the study of circulating layers of water in the Powder Hole. In 1909, in 18 feet of water, boxes containing quahaugs of the same size were suspended from the raft at 5, 10 and 15 feet. The gain in these boxes in terms of the standard for four and one-half months was 536 per cent., 554 per cent. and 438 per cent., respectively. The maximum growth occurred between 5 and 10 feet, and is intimately associated with the circulation in the Powder Hole, only the upper layer of water, above 10 feet, being disturbed by the inflowing tide.

Soil. — The quahaug is found in nearly every kind of soil, — gravel, sand and mud all seem alike to this mollusk. It is found in hard soil, into which it is difficult to force a rake, and in soft mud, where the gatherer sinks ankle deep. The best soil, if such can be designated, is a mixture of sand and mud, sufficiently loose to permit easy raking. The important consideration is the effect of the various soils on the growth and condition of the quahaug, rather than whether the animal can live. Organic acids in certain soils affect the composition of the shell, and through their irritating influence retard the growth by increasing the repairing processes. The kind of soil also affects the composition and shape of the shell, coarse, gravelly soil, especially in the case of the soft clam, giving a heavy, rough shell, in contrast to the thin paper-shell variety of the fine sand clam. In one instance quahaugs on a soft mud bottom had developed an elongate shell. In general, the soil has little influence upon the growth of the quahaug, and acts only as a resting place. The popular idea that the quahaug procures its nourishment from the soil, like a vegetable, is entirely erroneous, as the animal obtains its food from the water. The nature of the soil indirectly modifies the food supply, as certain soils are more prolific breeding grounds of the microscopic forms which make up the food of the quahaug.

(1) *Growth in Wire Cages.* — Kellogg (2) first described the growth of quahaugs in wire racks out of sand. Our experiments along this line were made with the view of developing a method of keeping quahaugs for the market without bedding in the sand. Wire cages, 1½ by 1 by ¼ feet, of ¼ to 1¼ inch mesh, were suspended in 1906 and 1907 from the raft at Monomoy Point. The annual growth was 12.87 millimeters, as compared with 23.53 millimeters for quahaugs in the sand boxes under the same conditions. A greater difference was found in 1909 with larger quahaugs (69 millimeters), which showed one-fourth the gain of the quahaugs in the sand boxes. The slower growth in the wire cages was due to the unnatural environment, which interfered with the natural feeding habits, and to the encrusting of the shells with barnacles, Serpula, Anomia, Crepidula and oysters, which use the same food. The experiment demonstrates that soil has little effect on shell formation, the quahaug obtaining its food and mineral salts from the water; and that quahaug culture in wire cages is impracticable, because it yields poor returns and is an expensive method of holding the catch for market.

(2) *Mud v. Sand.* — A comparison of the growth in mud and sand under similar conditions was made at Monomoy Point by suspending quahaugs of the same size from the raft in two boxes, one containing a sticky, black mud, the other clean, coarse sand. The increase in volume for the mud was 342 per cent. and 424 per cent. for the sand, which shows that the actual type of soil is of little consequence.

(3) *Eelgrass.* — The soil exerts an indirect influence on growth by the abundance or scarcity of eelgrass, which if thick prevents the free circulation of water over the bed. In addition to the examples cited under "Current," a comparison of experiments Nos. 186 and 187 on Egobert's Flat, Plymouth harbor, gives an annual growth of 11.73 millimeters for the clear and 7.43 millimeters for the eelgrass, although both beds were near together. The presence of eelgrass is not necessarily an indication of slow growth, as it only becomes a detriment when thick enough to interfere with the circulation.

Salinity. — The amount of salts in solution, although it may influence the spawning, does not materially affect the growth of the quahaug. Experimental beds, located in densities from 1.009 (less than one-half the ordinary salt content) to 1.026 (fairly high salt content), have shown no appreciable effects. In the laboratory, quahaugs have been kept alive in tanks in which the water, by evaporation, reached a salinity of 1.035. They have also been found in rivers with a daily variation in density from 1.015 to 1.022. Salinity, however, indirectly affects growth by modifying the food supply, brackish waters being more productive of diatoms.

Dwarf Quahaugs. — Quahaugs, like the higher animals, vary in their individual growth. Occasionally a specimen exhibits a consistently slow growth, either from an unfavorable position or from impaired feeding power. In case of defective nutrition shell formation will be slow for a number of years, and even for life. In one experimental bed a dwarf quahaug showed an annual growth of 6 millimeters, compared with an average of 9.35 millimeters in 1907; 4 millimeters, with 8.33 millimeters in 1908; and 5 millimeters, with 7.83 millimeters in 1909, which was less than two-thirds its normal growth.

Growth under Adverse Conditions. — In localities where conditions are at all unfavorable, 30 to 40 millimeter quahaugs grow more rapidly than smaller sizes, in direct contrast to growth under favorable conditions, where the 15-millimeter quahaug exhibits the greatest growing power. In the shore beds at Monomoy Point, where the environment proved a hindrance to rapid growth, 1,700 measurements gave a gain of 3.93 millimeters for quahaugs between 24 and 30 millimeters, compared with 4.93 millimeters for quahaugs between 30 and 40 millimeters. This difference is best explained by the ability of the larger quahaugs to combat the adverse conditions.

Growth in Thickly Planted Beds. — Nature regulates thick sets of clams or quahaugs by the simple process of gradually forcing out the superfluous shellfish, and leaving only the maximum number per square foot that the soil will support. If the bed has a poor circulation of water an overpopulation may cause an insufficient food supply and slower growth than if less thickly planted. The number per square foot which will give the best growth in any locality can be determined

only by experiment, the planter gradually increasing his stock until the maximum production is reached. In the boxes at Monomoy Point various numbers of 1½-inch quahaugs, from 7 to 90 per square foot, gave uniform results. The box containing 90 to the square foot, which was so crowded that several were forced out of the sand, showed about two-thirds the growth of the others. This experiment only illustrates the effect of crowding, and has no practical bearing on the maximum production of a large grant, which is entirely a question of the food supply.

Transplanting. — Transplanted quahaugs do not at first exhibit their usual rate of growth, as they take some time to become accustomed to their new environment. In planting between the tide lines at Wellfleet, where the quahaugs are exposed to the action of the waves and shifting sand, a sufficient time, about one month, is necessary for the regulation of the feeding habits. This fact should be borne in mind in determining the growth for any locality, as described under "Tables," and no less than two months be taken for the test. It is an advantage to plant in April, which affords an opportunity for the quahaugs to become accustomed to their surroundings before growth begins, May 1. The period of acclimatization is an extremely variable factor, depending on the size of the quahaugs, the date of planting (the period being longer in the fall), length of time out of water, and the change in environment. The decrease in growth from a complete change in environment and late planting is shown in the wire cages in 1906 and 1907. The quahaugs were placed in their new surroundings Sept. 18, 1906. The calculated rate of growth for 1906, 6.41 millimeters, was only one-half that of 1907, 12.87 millimeters, owing to the subnormal growth during September and October. Similarly, quahaugs transplanted from Nantucket to the raft boxes at Monomoy Point gave a calculated rate of 16.58 millimeters for 1906, as compared with 23.13 millimeters for 1907.

Growth in Boxes.— From a comparison of sand boxes and beds under the same condition it was found that growth was invariably faster in the boxes. The same results had been recorded in clam experiments on the Plymouth flats, where faster growth was obtained in boarded beds raised above the flat. Near Egg Island, Wellfleet, 3 box beds averaged an annual gain of 29.12 millimeters, compared with 12.06 millimeters for 13 ordinary beds. The idea that drainage was the cause was disproved by similar results being obtained below low-water mark at Monomoy Point. Boxes with sides of different heights were tried, to determine if these in some way aided the feeding, and boxes large and small, without sides, with and without bottoms, were used, but no appreciable difference was found; yet in every case growth was faster in the boxes than in the control beds. Also, the distance from the bottom, as demonstrated by a series of boxes arranged in the

form of steps, made no difference. An explanation, which in part accounted for this curious result, arose from the situation of these beds. In all cases the beds at certain times were exposed to wave action, which caused a slight shifting of sand, presumably enough to interfere with the feeding. The quahaugs in the boxes were protected from this action and were given better opportunity for feeding.

TABLES.

The following tables, which were formulated during the investigation, are presented for the use of the quahaug culturist in determining the productivity of new ground. The last, Table V, gives the summarized results from 187 experimental beds.

The method of procedure in determining the growth on a prospective grant for a series of years by means of these tables is as follows: —

(1) The culturist must obtain the growth for a definite period of not less than two months by planting a small experimental bed with quahaugs of a known size. The simplest way is to notch the edges with a file and the new growth can readily be measured when the quahaugs are taken up. The reasons for having the growing period no less than two summer months is due to the slow growth immediately after transplanting, as described under "Transplanting." The planter then has at hand the following data: (1) size planted; (2) gain in length for a certain known time, *i.e.*, 40-millimeter quahaugs grew to 48.92 millimeters, a gain of 8.92 millimeters from July 1 to September 1.

(2) By means of Table I. (monthly values) we find that the growth during July and August is 44.58 per cent. of the total yearly growth, which is therefore 20 millimeters.

(3) Table II. reduces the gain of a 40-millimeter quahaug to that of a 25-millimeter, which is used as a uniform standard in the experiments of this department, by multiplying with the factor 1.353, and in this example the result will be 27.06 millimeters.

(4) By Table III. the gain in volume is obtained by dividing the water displacement or number per quart of a 52.06-millimeter quahaug by that of a 25-millimeter, which gives 709 per cent., or 8 quarts for every quart planted.

(5) By Table IV. the growth on the grant can be calculated to five and one-half years. In the case of a gain of 20 millimeters for a 25-millimeter quahaug, the figures would read ½ year 5 millimeters; 1½, 28.30 millimeters; 2½, 46.98 millimeters; 3½, 59.85 millimeters; 4½, 69.46 millimeters; 5½, 76.64 millimeters (25.4 millimeters equal 1 inch).

Value of the Different Months. — The quahaug only increases the size of the shell during the summer months, and at a variable rate, the months of August and September showing the fastest growth. The table

is taken from the monthly measurements of quahaugs from the raft boxes and beds at Monomoy Point, and the value of the various months is presented in terms of the gain for a standard quahaug of 25 millimeters. Each month is given a number representing the gain in per cent., the entire year being considered as 100 per cent.

Table I.

Month.	Per Cent.	Month.	Per Cent.
January,		August,	25.56
February,		September,	26.24
March,		October,	12.85
April,	-	November,	1.74
May,	3.78	December,	
June,	10.81		100.00
July,	19.02		

Size and Growth. — In recording the growth of a large number of various sized quahaugs under the same conditions in the raft boxes at Monomoy Point sufficient data were obtained to formulate a table giving the comparative annual increase in length for quahaugs from 1 to 100 millimeters in size. If, for example, a 25-millimeter quahaug, which is taken as a standard size in our experiments, gained 23 millimeters, a 50-millimeter quahaug would gain 13.9 millimeters, and a 75-millimeter quahaug 6.6 millimeters in the same time. From these measurements factors were obtained which by multiplication would transform the growth of any sized quahaug into terms of the standard 25-millimeter quahaug. This table was of great assistance in reducing the experimental data to uniform figures when it was impossible to obtain the standard size for planting.

According to the table the size of 14 millimeters gives the best growth, all larger sizes gradually decreasing. Theoretically, as shown in the table, the sizes below 14 millimeters reversely exhibit slower growth, but practically this is somewhat offset by the increase in velocity, as the quahaug grows toward 14 millimeters in size, *i.e.*, a 5-millimeter quahaug practically would gain 26.80 millimeters, although theoretically its initial growing power would only be 20.02 millimeters at the same rate according to the table.

Table II.

Size in Millimeters.	Factor.	Size in Millimeters.	Factor.	Size in Millimeters.	Factor.
1,	2.875	35,	1.223	69,	2.738
2,	1.840	36,	1.243	70,	2.840
3,	1.474	37,	1.271	71,	2.949
4,	1.278	38,	1.299	72,	3.067
5,	1.139	39,	1.329	73,	3.194
6,	1.046	40,	1.353	74,	3.333
7,	.979	41,	1.377	75,	3.485
8,	.931	42,	1.411	76,	3.651
9,	.895	43,	1.438	77,	3.833
10,	.868	44,	1.465	78,	4.035
11,	.649	45,	1.494	79,	4.259
12,	.836	46,	1.523	80,	4.510
13,	.830	47,	1.554	81,	4.792
14,	.830	48,	1.586	82,	5.055
15,	.833	49,	1.620	83,	5.349
16,	.849	50,	1.655	84,	5.679
17,	.865	51,	1.691	85,	6.053
18,	.881	52,	1.729	86,	6.479
19,	.895	53,	1.769	87,	6.970
20,	.913	54,	1.804	88,	7.541
21,	.927	55,	1.840	89,	8.215
22,	.947	56,	1.886	90,	9.200
23,	.962	67,	1.933	91,	10.000
24,	.979	58,	1.983	92,	10.952
25,	1.000	59,	2.035	93,	12.105
26,	1.022	60,	2.091	94,	13.143
27,	1.046	61,	2.140	95,	14.839
28,	1.065	62,	2.191	96,	16.788
29,	1.085	63,	2.289	97,	17.500
30,	1.106	64,	2.347	98,	23.000
31,	1.127	65,	2.421	99,	28.750
32,	1.150	66,	2.500	100,	38.333
33,	1.174	67,	2.570		
34,	1.198	68,	2.644		

Size and Volume. — The mere statement of the gain in length does not adequately express the actual increase, which should be stated in terms of volume. The tight shell of the quahaug makes easy the exact determination of the volume by water displacement. A quahaug 25 millimeters (about 1 inch in length) displaces 3 cubic centimeters of water, while 51 millimeters (about 2 inches in length) is not merely twice as large, as the measurements indicate, but, displacing 22.8 cubic centimeters, has a volume of 7.6 times the first, a true index of the actual increase. In preparing the following table the water displacements of a large number of quahaugs from 1 to 88 millimeters were taken. Owing to the variation in the individual quahaugs, several hundred were used to obtain the displacement for each size, except in the cases of the quahaugs below 10 millimeters, which were difficult to obtain. From this table the gain in volume for any size and growth can be readily determined.

Table III.

Size in Millimeters.	Volume in Cubic Centimeters.	Number per Quart.	Size in Millimeters.	Volume in Cubic Centimeters.	Number per Quart.
1,	.007	100,714	25,	3.000	235
2,	.013	54,231	26,	3.400	207
3,	.021	33,572	27,	3.820	185
4,	.032	22,031	28,	4.250	166
5,	.043	16,396	29,	4.700	150
6,	.056	12,589	30,	5.170	136
7,	.072	9,790	31,	5.670	124
8,	.091	7,747	32,	6.180	114
9,	.133	5,299	33,	6.700	105
10,	.191	3,691	34,	7.250	97.25
11,	.255	2,764	35,	7.800	90.35
12,	.313	2,252	36,	8.400	83.92
13,	.393	1,794	37,	9.050	77.90
14,	.490	1,439	38,	9.750	72.31
15,	.600	1,175	39,	10.500	67.14
16,	.718	982	40,	11.300	62.39
17,	.848	831	41,	12.000	58.75
18,	.998	706	42,	12.900	54.65
19,	1.210	583	43,	13.800	51.09
20,	1.440	489	44,	14.800	47.63
21,	1.680	420	45,	15.800	44.64
22,	1.970	358	46,	16.900	41.72
23,	2.270	310	47,	18.000	39.17
24,	2.600	271	48,	19.000	37.11

Table III. — Concluded.

Size in Millimeters.	Volume in Cubic Centimeters.	Number per Quart.	Size in Millimeters.	Volume in Cubic Centimeters.	Number per Quart.
49, .	20.200	34.90	69, ...	55.200	12.77
50, .	21.500	32.79	70, ...	57.700	12.22
51,	22.800	30.92	71, ...	60.100	11.73
52, . .	24.200	29.13	72, ...	63.000	11.19
53, . . .	25.600	27.54	73, ...	65.700	10.73
54, . . .	26.900	26.21	74, ...	68.400	10.31
55, . .	28.300	24.91	75, . .	71.100	9.92
56, ...	29.800	23.66	76, ...	74.200	9.50
57, . . .	31.300	22.53	77, . .	77.300	9.12
58, . .	33.000	21.36	78, . . .	80.400	8.77
59, . . .	34.600	20.38	79, . .	83.900	8.40
60, .	36.300	19.42	80, . .	87.300	8.08
61, .	38.200	18.46	81, . . .	90.900	7.76
62, . . .	40.300	17.49	82, ...	95.000	7.42
63, .	42.400	16.63	83, . . .	99.500	7.09
64,	44.500	15.84	84, . . .	104.200	6.77
65, . . .	46.600	15.13	85, ...	109.000	6.47
66, . .	48.700	14.48	86, . . .	114.000	6.18
67, .	50.900	13.85	87, . .	118.700	5.94
68, . .	53.000	13.30	88, . . .	123.000	5.73

Standard Growth. — The growth in millimeters up to five and one-half years is given for various annual rates of growth, from 1 to 30 millimeters, of a standard 25-millimeter quahaug. Knowing the annual growth for a 25-millimeter quahaug, the reader can determine the size at any period up to five and one-half years by referring to the other columns.

Table IV.

Annual Rates in Millimeters for a 25-Millimeter Quahaug.	Size in Millimeters at Various Ages.					
	½ Year.	1½ Years.	2½ Years.	3½ Years.	4½ Years.	5½ Years.
1, .	5	5.89	6.84	7.85	8.92	10.03
2, ...	5	6.93	9.01	11.29	13.67	16.08
3, .	5	8.13	11.49	15.08	18.68	22.05
4, ...	5	9.19	13.68	18.60	23.00	27.16

Table IV. — Concluded.

Annual Rates in Millimeters for a 25-Millimeter Quahaug.	Size in Millimeters at Various Ages.					
	½ Year.	1½ Years.	2½ Years.	3½ Years.	4½ Years.	5½ Years.
5,	5	10.39	16.34	22.21	27.47	32.21
6,	5	11.63	18.86	25.57	31.50	36.78
7,	5	12.90	21.33	28.78	35.26	40.96
8,	5	14.19	23.83	32.03	38.98	45.00
9,	5	15.48	26.19	34.96	42.32	48.66
10,	5	16.65	28.29	37.63	45.39	52.03
11,	5	17.82	30.35	40.23	48.32	55.20
12,	5	18.98	32.39	42.74	51.13	58.20
13,	5	20.14	34.35	45.11	53.80	61.03
14,	5	21.31	36.31	47.49	56.41	63.75
15,	5	22.48	38.19	49.68	58.80	66.21
16,	5	23.64	40.08	51.88	61.17	68.62
17,	5	24.81	41.88	54.07	63.47	70.81
18,	5	25.97	43.59	55.97	65.52	72.83
19,	5	27.14	45.27	57.92	67.52	74.80
20,	5	28.30	46.98	59.85	69.46	76.64
21,	5	29.47	48.65	61.76	71.40	78.41
22,	5	30.64	50.29	63.50	72.99	79.88
23,	5	31.80	51.88	65.22	74.44	81.21
24,	5	32.97	53.43	66.81	76.20	82.71
25,	5	34.13	54.94	68.54	77.81	84.07
26,	5	35.30	56.45	70.08	79.22	85.25
27,	5	36.46	57.95	71.68	80.52	86.31
28,	5	37.63	59.36	72.98	81.75	87.36
29,	5	38.79	60.72	74.36	82.92	88.40
30,	5	39.96	62.15	75.75	84.06	89.32

The Experimental Beds. — This table gives a summary of the experiments of this department. The current is represented by numbers from 1 to 5, according to its velocity, 1 indicating still water and 5 a rapid flow. The average annual growth and increase in volume is given in terms of a 25-millimeter quahaug, which has been taken as an arbitrary standard for the sake of comparison. The size, in terms of the length, at various ages is given in yearly intervals from one-half to five and one-half years, starting with the average length of 5 millimeters.

Table V.

No. of Experiment.	Location.	Current.	Soil.	Depth of Water in Feet at Low Tide.	Salinity.	Annual Growth in Millimeters.	Gain Per Cent. in Volume.	Size in Millimeters at Various Ages.						Remarks.
								½ Yr.	1½ Yrs.	2½ Yrs.	3½ Yrs.	4½ Yrs.	5½ Yrs.	
1	Nantucket, Polyps harbor,	2	Compact mud, .	.3	1.009	8.48	132	5	14.81	24.98	33.44	40.58	46.76	
2	Monument Beach, . .	2	Mud, . .	2.0	1.022	10.15	163	5	16.83	28.75	38.15	45.93	52.59	
3	Monomoy, east side of Powder Hole.	1	Coarse sand, .	2.5	1.022	8.91	140	5	15.38	25.98	34.70	42.02	48.33	Bed near shore.
4	Monomoy, south side of Powder Hole.	2	Coarse sand, .	2.5	1.022	10.27	165	5	16.97	28.85	38.33	46.18	52.89	Bed near shore.
5	Monomoy, south side of Powder Hole.	2	Coarse sand, .	2.5	1.022	13.37	234	5	20.57	35.08	45.99	54.77	61.94	Bed near shore.
6	Monomoy, south side of Powder Hole.	2	Coarse sand, .	2.5	1.022	12.81	221	5	19.92	33.98	44.66	53.29	60.49	Bed near shore.
7	Monomoy, south side of Powder Hole.	2	Coarse sand, .	2.0	1.022	12.09	204	5	19.08	32.57	42.95	51.37	58.46	Bed near shore.
8	Monomoy, east side of Powder Hole.	2	Coarse sand, .	2.0	1.022	9.53	151	5	16.10	27.30	36.38	43.95	50.45	Bed near shore.
9	Monomoy, flat, . . .	2	Coarse sand, .	Exposed.	1.024	4.78	69	5	10.13	15.75	21.39	26.49	31.10	Shifting sand.
10	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	18.87	389	5	26.99	45.05	57.67	67.36	74.54	Sand box.
11	Monomoy, raft, . .	4	Coarse sand, .	4.5	1.024	23.07	536	5	31.88	51.99	65.33	74.56	81.32	Sand box.
12	Monomoy, raft, . .	4	Coarse sand, .	6.5	1.024	22.30	510	5	30.98	50.77	64.02	73.43	80.28	Sand box.
13	Monomoy, raft, . . .	4	Coarse sand, .	5.5	1.024	27.58	734	5	37.14	58.77	72.30	81.23	86.92	Sand box.
14	Monomoy, raft, . .	4	Coarse sand, .	5.5	1.024	25.50	638	5	34.72	55.70	69.31	78.52	84.86	Sand box.
15	Monomoy, raft, . .	4	Coarse sand, .	5.5	1.024	21.58	488	5	30.27	49.77	62.94	72.48	79.41	Sand box.
16	Monomoy, raft, . . .	4	Coarse sand, .	4.0	1.024	21.40	478	5	29.93	49.31	62.46	72.04	79.06	Sand box.
17	Monomoy, raft, . .	4	Coarse sand, .	4.5	1.024	25.12	622	5	34.27	55.12	68.72	77.98	84.21	Sand box.
18	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	24.73	605	5	33.82	54.53	68.07	77.38	83.70	Sand box.

19	Monomoy, raft, . . .	4	Coarse sand, .	3.5	1.024	25.00	617	5	34.13	54.94	68.54	77.81	84.07	Sand box.
20	Monomoy, raft, . . .	4	Coarse sand, .	5.0	1.024	20.37	440	5	28.73	47.60	60.56	70.18	77.29	Sand box.
21	Monomoy, raft, .	4	Coarse sand, .	4.5	1.024	25.08	620	5	34.22	55.06	68 66	77.92	84.16	Sand box.
22	Monomoy, middle of Powder Hole.	3	Coarse sand, .	11.0	1.024	13.98	250	5	21.29	36.27	47.45	56.36	63.70	Sand box.
23	Monomoy, raft, . .	4	Coarse sand, .	4.0	1.024	26.09	664	5	35.40	56.59	70.22	79.34	85.35	Sand box.
24	Monomoy, south side of Powder Hole.	2	Coarse sand, .	.5	1.022	17.42	343	5	25.30	42.60	54.87	64.33	71.66	Sand box.
25	Monomoy, south side of Powder Hole.	2	Coarse sand, .	.5	1.022	14.26	257	5	21.61	36.80	48.06	57.05	64.40	Sand box.
26	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	25.11	621	5	34.26	55.11	68.71	77.97	84.20	Sand box.
27	Monomoy, raft, . .	4	Coarse sand, .	9.0	1 024	21.81	493	5	30.42	49.98	63.17	72.66	79.60	Sand box.
28	Monomoy, raft, .	4	Coarse sand, .	8.0	1.024	21.23	472	5	29.74	49.03	62.16	71.77	78.75	Sand box.
29	Monomoy, raft, . .	4	Coarse sand, .	11.0	1.024	24.31	587	5	33.33	53.90	67.35	76.70	83.13	Sand box.
30	Monomoy, raft, . .	4	Coarse sand, .	3.0	1.024	24.18	581	5	33.18	53.70	67.12	76.49	82.95	Sand box.
31	Monomoy, raft, . .	4	Coarse sand, .	8.0	1.024	24.66	602	5	33.74	54.43	67.95	77.26	83.61	Sand box.
32	Monomoy, middle of Powder Hole.	3	Coarse sand, .	11.0	1.024	14.78	271	5	22.21	37.77	49.19	58.27	65.70	Sand box.
33	Monomoy, raft, . .	4	Coarse sand, .	7.0	1.024	21.91	497	5	30.53	50.14	63.34	72.85	79.75	Sand box.
34	Monomoy, raft, . .	4	Coarse sand, .	3.5	1.024	21.41	478	5	29.95	49.32	62.47	72.05	79.01	Sand box.
35	Monomoy, edge of clam flat,	4	Coarse sand, .	1.0	1.024	19.76	419	5	28.02	46.57	59.39	68.99	76.20	Sand box.
36	Monomoy, raft, . .	4	Coarse sand, .	2.0	1.024	14.13	253	5	21.46	36.55	47.82	56.74	64.07	Sand box, planted late in the season.
37a	Monomoy, south side of Powder Hole.	2	Coarse sand, .	.8	1.022	7.51	115	5	13.55	22.61	30.44	37.16	43.02	Sand box.
37b	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	9.22	145	5	15.86	26.86	35.81	43.30	49.74	Sand box.
37c	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.3	1.022	1.14	15	5	6.04	7.14	8.33	9.59	10.88	
38a	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	7.31	111	5	13.30	22.11	29.79	36.41	42.21	Sand box.

Table V. — Continued.

No. of Experiment.	Location.	Current.	Soil.	Depth of Water in Feet at Low Tide.	Salinity.	Annual Growth in Millimeters.	Gain Per Cent. in Volume.	Size in Millimeters at Various Ages.						Remarks.
								½ Yr.	1½ Yrs.	2½ Yrs.	3½ Yrs.	4½ Yrs.	5½ Yrs.	
38b	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	6.58	99	5	12.37	20.29	27.48	33.68	39.20	Sand box.
38c	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	7.80	120	5	13.93	23.33	31.38	38.24	44.19	Sand box.
38d	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	7.20	109	5	13.16	21.83	29.43	36.00	41.77	Sand box.
39a	Monomoy, raft, . .	4	Coarse sand, .	7.0	1.024	11.03	181	5	17.85	30.41	40.31	48.41	55.29	Sand box, covered.
39b	Monomoy, raft, .	4	Coarse sand, .	7.0	1.024	13.16	229	5	20.32	34.67	45.49	54.22	61.47	Sand box, uncovered.
40a	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	22 07	502	5	30.72	50.40	63.62	73.00	79.97	Sand box, 90 quahaugs per square foot.
40b	Monomoy, reft,	4	Coarse sand, .	6.0	1.024	23.44	551	5	32.31	52.56	65.93	75.21	81.87	Sand box, 60 quahaugs per square foot.
40c	Monomoy, raft,	4	Coarse sand, .	6.0	1.024	25.01	617	5	34.14	54.96	68.66	77.82	84.08	Sand box, 45 quahaugs per square foot.
40d	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	25.16	624	5	34.32	55.16	68.79	78.04	84.26	Sand box, 22 quahaugs per square foot.
40e	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	21.10	467	5	29.59	48.81	61.93	71.56	78.56	Sand box, 7 quahaugs per square foot.
41a	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	7.73	119	5	13.84	23.15	31.15	37.98	43.91	Sand box, 60 quahaugs per square foot.
41b	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	10.08	162	5	16.74	28.45	37.83	45.62	52.28	Sand box, 45 quahaugs per square foot.
41c	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	8.38	130	5	14.68	24.73	33.14	40.25	46.39	Sand box, 22 quahaugs per square foot.
41d	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	6.08	90	5	11.73	19.06	25.83	31.80	37.11	Sand box, 7 quahaugs per square foot.
42	Monomoy, clam flat, .	4	Coarse sand, .	Exposed.	1.024	11.71	19	5	18.64	31.80	42.01	50.32	57.33	
43	Monomoy, clam flat, .	4	Coarse sand, .	Exposed.	1.024	6.39	96	5	12.13	19.82	26.82	32.97	38.41	
44	Monomoy, edge of clam flat,	4	Coarse sand, .	1.0	1.024	21.28	474	5	29.80	49.11	62.24	71.85	78.82	Sand box.
45	Monomoy, raft, . .	4	Coarse sand,	5.0	1.024	23.45	551	5	32.33	52.58	66.04	75.23	81.89	Sand box.

46	Monomoy, raft,	4	Coarse sand, .	5.0	1.024	9.10	143	5	15.50	26.40	35.23	42.63	49.00	Wire cage.
47	Monomoy, raft, .	4	Coarse sand, .	6.5	1.024	10.74	175	5	17.52	29.81	39.55	47.66	54.38	Wire cage.
48	Monomoy, raft,	4	Coarse sand, .	5.0	1.024	8.29	129	5	14.56	24.51	32.88	39.95	46.06	Wire cage.
49	Monomoy, south side of Powder Hole.	2	Coarse sand, .	.3	1.022	12.47	213	5	19.53	33.31	43.85	52.38	59.53	Sand box.
50a	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	21.57	484	5	30.14	49.58	62.76	72.31	79.25	Sand box.
50b	Monomoy, east side of Powder Hole.	1	Coarse sand, .	2.0	1.022	9.87	158	5	16.50	28.02	37.28	44.90	51.59	Sand box.
50c	Monomoy, east side of Powder Hole.	1	Coarse sand, .	2.5	1.022	8.91	140	5	15.36	25.98	34.70	42.02	48.33	
51	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	19.13	397	5	27.29	45.96	58.52	68.05	76.82	Sand box.
52	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	21.16	469	5	29.66	48.91	62.04	71.65	78.65	Sand box.
53	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	19.91	424	5	28.20	46.83	59.68	69.29	76.47	Sand box.
54	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.0	1.022	17.91	357	5	25.87	43.44	55.80	65.34	72.65	Sand box.
55	Monomoy, south side of Powder Hole.	2	Coarse sand, .	2.0	1.022	18.42	374	5	26.46	44.30	56.79	66.36	73.66	
56	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1 5	1.022	17.11	333	5	24.94	42.07	54.28	63.60	71.03	Sand box.
57	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.5	1.022	16.55	317	5	24.18	41.07	53.08	62.44	69.82	Sand box.
58	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.5	1.022	16.25	308	5	23.93	40.53	52.43	61.75	69.17	Sand box.
59	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.5	1.022	19.03	394	5	27.17	45.32	57.98	67.58	74.85	Sand box.
60	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.5	1.022	15.56	290	5	23.13	39.25	50.91	60.13	67.56	Sand box.
61	Monomoy, south side of Powder Hole.	2	Coarse sand, .	1.5	1.022	13.45	236	5	20.67	35.25	46.18	54.97	62.25	Sand box.
62	Monomoy, east side of Powder Hole.	1	Coarse sand, .	1.5	1.022	14.07	252	5	21.39	36.44	47.64	56.58	63.92	Sand box.
63	Monomoy, east side of Powder Hole.	1	Coarse sand, .	1.5	1.022	13.23	231	5	20.41	34.81	45.66	54.40	61.66	Sand box.
64	Monomoy, east side of Powder Hole.	1	Coarse sand, .	1.5	1.022	14.85	273	5	22.30	37.91	49.35	58.44	65.84	Sand box.
65	Monomoy, east side of Powder Hole.	1	Coarse sand, .	1.5	1.022	12.11	204	5	19.11	32.62	43.00	51.42	58.51	Sand box.

Table V. — Continued.

No. of Experiment.	Location.	Current.	Soil.	Depth of Water in Feet at Low Tide.	Salinity.	Annual Growth in Millimeters.	Gain Per Cent. in Volume.	Size in Millimeters at Various Ages.						Remarks.
								½ Yr.	1½ Yrs.	2½ Yrs.	3½ Yrs.	4½ Yrs.	5½ Yrs.	
66	Monomoy, east side of Powder Hole.	1	Coarse sand, .	1.5	1.022	12.63	216	5	19.71	33.62	44.23	52.81	59.98	Sand box.
67	Monomoy, edge of clam flat,	4	Coarse sand, .	1.5	1.024	10.95	179	5	17.76	30.25	40.10	48.17	55.04	Sand box.
68	Monomoy, edge of clam flat,	4	Coarse sand, .	1.5	1.024	8.63	139	5	15.26	25.79	34.46	41.75	46.04	Sand box.
69	Monomoy, edge of clam flat,	4	Coarse sand, .	1.5	1.024	11.60	193	5	18.52	31.57	41.74	50.01	57.00	Sand box.
70	Monomoy, edge of clam flat,	4	Coarse sand, .	1.5	1.024	12.61	216	5	19.69	33.59	44.19	52.76	59.93	Sand box.
71	Monomoy, edge of clam flat,	4	Coarse sand, .	1.5	1.024	15.28	283	5	23.78	40.30	52.14	61.44	68.88	Sand box.
72	Monomoy, raft, . .	4	Coarse sand,	5.0	1.024	27.16	714	5	36.64	56.06	71.79	80.70	86.47	Sand box.
73	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	25.66	645	5	34.90	55.14	69.56	78.74	84.85	Sand box.
74	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	25.23	627	5	34.40	55.20	68.89	78.13	84.34	Sand box.
75	Monomoy, raft,	4	Coarse sand,	5.0	1.024	25.94	657	5	35.23	56.36	69.99	79.14	85.18	Sand box.
76	Monomoy, raft, .	4	Coarse sand,	5.0	1.024	25.99	660	5	35.29	56.43	70.06	79.21	85.24	Sand box.
77	Monomoy, raft, .	4	Coarse sand, .	5.0	1.024	24.16	580	5	33.16	53.67	67.09	76.46	82.93	Sand box.
78	Monomoy, raft,	4	Coarse sand, .	5.0	1.024	25.50	638	5	34.72	55.70	69.31	78.52	64.66	Sand box.
79	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	25.68	646	5	34.93	55.97	69.59	78.77	84.87	Sand box.
80	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	26.41	634	5	35.78	57.07	70.70	79.75	85.68	Sand box.
81	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	26.21	670	5	35.55	56.77	70.40	79.49	85.47	Sand box.
82	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	23.33	547	5	32.19	52.40	65.75	75.03	81.71	Sand box.
83	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	25.25	628	5	34.43	55.32	68.93	78.17	84.37	Sand box.

84	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	24.59	599	5	33.65	54.34	67.83	77.05	83.51	Sand box.
85	Monomoy, raft,	4	Coarse sand, .	6.0	1.024	26.12	666	5	35.44	56.63	70.26	79.38	85.38	Sand box.
86	Monomoy, raft,	4	Coarse sand, .	6.0	1.024	19.14	398	5	27.30	45.61	58.19	67.79	75.06	Sand box.
87	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	20.38	441	5	28.74	47.61	60.58	70.20	77.31	Sand box.
88	Monomoy, raft,	4	Coarse sand, .	6.0	1.024	24.74	605	5	33.83	54.57	68.09	77.39	83.72	Sand box.
89	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	20.42	442	5	28.79	47.68	60.65	70.27	77.36	Sand box.
90	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	25.91	656	5	35.19	56.31	69.94	79.09	85.14	Sand box.
91	Monomoy, raft, . .	4	Coarse sand,	6.0	1.024	25.80	651	5	35.07	56.15	69.77	78.94	85.01	Sand box.
92	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	22.66	529	5	31.64	51.66	64.98	74.24	81.02	Sand box.
93	Monomoy, raft, . .	4	Coarse sand, .	6.0	1.024	21.91	497	5	30.53	50.14	63.34	72.85	79.75	Sand box.
94	Monomoy, raft, .	4	Coarse sand, .	6.0	1.024	26.12	666	5	35.44	56.63	70.26	79.38	85.38	Sand box.
95	Monomoy, raft,	4	Coarse sand, .	15.0	1.024	21.36	477	5	29.89	49.24	62.39	71.98	78.94	Sand box.
96	Monomoy. raft, .	4	Coarse sand, .	5.0	1.024	25.00	617	5	34.13	54.94	68.54	77.61	84.07	Sand box.
97	Monomoy, raft,	4	Coarse sand, .	10.0	1.024	23.76	564	5	32.69	53.06	66.43	75.78	82.35	Sand box.
98	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	26.86	700	5	36.31	57.74	71.37	80.34	86.16	Sand box.
99	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	26.23	671	5	35.57	56.80	70.43	79.52	85.49	Sand box.
100	Monomoy, raft, .	4	Coarse sand, .	5.0	1.024	25.84	653	5	35.11	56.21	69.83	78.99	85.06	Sand box.
101	Wellfleet, north of Egg Island.	5	Coarse sand, .	Exposed.	1.024	27.21	716	5	36.71	58.25	71.88	80.78	86.53	Sand box.
102	Wellfleet, north of Egg Island.	5	Sand, .	Exposed.	1.024	29.47	819	5	39.34	61.39	75.01	83.46	88.83	Sand box.
103	Wellfleet, north of Egg Island.	5	Sand, . .	Exposed.	1.024	31.09	903	5	41.23	63.69	77.08	84.16	89.58	Sand box.
104	Wellfleet, north of Egg Island,	5	Sand, . .	Exposed.	1.024	26.72	694	5	36.14	57.53	71.16	80.16	86.01	Sand box.
105	Wellfleet, north of Indian Neck.	5	Sand, . .	Exposed.	1.024	20.52	446	5	28.91	47.85	60.84	70.47	77.56	

Table V. — Continued.

No. of Experiment.	Location.	Current.	Soil.	Depth of Water in Feet at Low Tide.	Salinity.	Annual Growth in Millimeters.	Gain Per Cent. in Volume.	Size in Millimeters at Various Ages. ½ Yr.	1½ Yrs.	2½ Yrs.	3½ Yrs.	4½ Yrs.	5½ Yrs.	Remarks.
106	Wellfleet, north of Indian Neck.	4	Sandy mud, .	Exposed.	1.024	19.50	315	5	24.23	40.98	52.98	62.32	69.72	
107	Wellfleet, north of Indian Neck.	2	Sandy mud, .	Exposed.	1.024	3.88	55	5	9.06	13.42	18.09	22.48	26.55	Bed high, near shore.
108	Wellfleet, south side of Herring River.	5	Sandy mud, .	Exposed.	1.022	21.78	492	5	30.38	49.93	63.12	72.64	79.56	
109	Wellfleet, south side of Herring River.	5	Sandy mud, .	Exposed.	1.022	19.81	420	5	28.08	46.66	59.48	69.09	79.29	
110	Wellfleet, south side of Herring River.	2	Sandy mud, .	Exposed.	1.022	6.06	90	5	11.71	19.01	25.76	31.73	37.03	Bed high, near shore.
111	Wellfleet, south side of Herring River.	5	Sand, . .	Exposed.	1.022	27.92	750	5	37.54	59.25	72.87	81.65	89.28	
112	Wellfleet, south side of Herring River.	1	Soft mud, .	Exposed.	1.022	1.83	25	5	6.75	8.64	10.71	12.80	15.05	Mud hole in thatch.
113	Wellfleet, south side of Blackfish Creek.	4	Coarse sand, .	Exposed.	1.024	9.09	144	5	15.59	26.38	35.20	42.60	48.99	
114	Wellfleet, south side of Blackfish Creek.	5	Coarse sand, .	Exposed.	1.024	13.32	233	5	20.51	33.03	45.87	54.64	81.90	
115	Wellfleet, north side of Blackfish Creek.	4	Sand, . .	Exposed.	1.024	8.32	129	5	14.60	24.59	32.97	40.05	49.17	
116	Wellfleet, west of Indian Neck.	4	Sand, . .	Exposed.	1.024	6.83	100	5	12.43	20.42	27.59	33.87	39.41	Exposed longer than No. 117.
117	Wellfleet, west of Indian Neck.	4	Sand, . .	Exposed.	1.024	13.32	233	5	20.51	35.03	45.87	54.64	61.90	
118	Plymouth harbor, Grey's Flat.	4	Mud, . .	Exposed.	1.021	9.07	143	5	15.59	26.34	35.15	42.53	48.90	
119	Wellfleet, west of Indian Neck.	4	Shifting sand, .	Exposed.	1.024	9.52	153	5	18.09	27.28	36.35	43.92	50.41	
120	Wellfleet, west of Indian Neck.	4	Sand, . .	Exposed.	1.024	8.25	128	5	14.51	24.42	32.77	39.82	45.92	Near shore.
121	Wellfleet, west of Indian Neck.	4	Sand, .	Exposed.	1.024	12.34	210	5	19.37	33.06	43.55	52.04	59.19	
122	Wellfleet, north side of Blackfish Creek.	4	Sand, .	Exposed.	1.024	10.86	177	5	17.68	30.08	39.87	47.01	54.78	
123	Wellfleet, north side of Blackfish Creek.	4	Sand, .	Exposed.	1.024	7.97	123	5	14.15	23.75	31.93	38.87	44.88	

124	Wellfleet, north side of Blackfish Creek.	4	Sand, . .	Exposed.	1.024	9.38	160	5	15.92	26.99	35.97	43.49	49.93	
125	Wellfleet, north side of Blackfish Creek.	3	Sand, . .	Exposed.	1.024	3.88	65	5	9.06	13.42	18.09	22.48	26.55	High, near shore.
126	Wellfleet, north side of Blackfish Creek.	4	Sand, . .	Exposed.	1.024	6.49	98	5	12.26	20.07	27.15	33.34	38.83	
127	Wellfleet, north side of Blackfish Creek.	3	Sand, . .	Exposed.	1.024	5.15	75	5	10.58	16.73	22.71	28.07	32.90	
128	Wellfleet, north side of Blackfish Creek.	3	Sand, . .	Exposed.	1.024	2.19	30	5	7.16	9.48	12.01	14.62	17.21	
129	Wellfleet, north side of Blackfish Creek.	4	Sand, . .	Exposed.	1.024	13.18	230	5	20.35	34.71	45.56	56.27	61.53	
130	Wellfleet, west of Indian Neck.	2	Sand, . .	Exposed.	1.024	5.57	82	5	11.10	17.78	24.13	29.77	34.81	High bed.
131	Wellfleet, west of Lieutenant's Island.	4	Sand, . .	Exposed.	1.024	13.89	248	5	21.17	36.13	47.23	56.12	63.45	
132	Wellfleet, west of Lieutenant's Island.	4	Sand,	Exposed.	1.024	8.39	130	5	14.69	24.75	33.17	40.28	46.43	
133	Wellfleet, west of Lieutenant's Island.	4	Sand, . .	Exposed.	1.024	7.05	107	5	12.96	21.46	28.94	35.45	41.16	
134	Wellfleet, west of Lieutenant's Island.	4	Sand, . .	Exposed.	1.024	11.42	189	5	18.31	31.21	41.28	49.50	56.46	
135	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	10.58	172	5	17.33	29.48	39.14	47.09	53.87	
136	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	12.90	223	5	20.02	34.15	44.87	53.53	60.75	
137	Wellfleet, Egg Island,	5	Coarse sand, .	Exposed.	1.024	15.93	298	5	23.56	39.95	51.73	61.00	68.45	
138	Wellfleet, Egg Island,	5	Coarse sand, .	Exposed.	1.024	12.90	223	5	20.02	34.15	44.87	53.53	60.75	
139	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	14.95	275	5	22.42	38.10	49.57	58.68	66.09	
140	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	15.72	293	5	23.32	39.55	51.26	60.51	67.95	
141	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	12.13	205	5	19.13	32.64	43.05	51.48	58.57	
142	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	9.52	151	5	16.09	27.28	36.35	43.92	50.41	
143	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	14.95	275	5	22.42	38.10	49.57	58.68	66.09	
144	Wellfleet, Egg Island, .	5	Coarse sand,	Exposed.	1.024	14.88	273	5	22.34	37.96	49.42	58.51	65.91	
145	Wellfleet, north of Egg Island.	5	Sand, . .	Exposed.	1.024	13.25	232	5	20.43	34.84	45.70	54.45	61.71	
146	Wellfleet, north of Egg Island.	3	Sand, . .	Exposed.	1.024	7.12	110	5	13.06	21.63	29.17	35.71	41.44	

Table V. — Concluded.

No. of Experiment.	Location.	Current.	Soil.	Depth of Water in Feet at Low Tide.	Salinity.	Annual Growth in Millimeters.	Gain Per Cent. in Volume.	Size in Millimeters at Various Ages.						Remarks.
								½ Yr.	1½ Yrs.	2½ Yrs.	3½ Yrs.	4½ Yrs.	5½ Yrs.	
147	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	10.93	179	5	17.74	30.21	40.05	46.11	49.98	
148	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	7.54	115	5	13.60	22.68	30.54	37.27	43.14	Near shore.
149	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	8.18	127	5	14.42	24.25	32.56	39.58	45.66	
150	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	9.59	152	5	16.17	27.43	36.54	44.13	50.65	
151	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	7.68	118	5	13.78	23.03	30.99	37.79	43.71	
152	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	3.74	55	5	8.91	13.11	17.81	21.68	25.83	High bed.
153	Wellfleet, Great Island Meadows.	3	Sand, .	Exposed.	1.024	9.66	154	5	16.25	27.58	36.72	44.35	50.88	
154	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	10.50	170	5	17.24	29.32	38.93	46.86	53.62	
155	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	7.97	123	5	14.15	23.75	31.93	38.67	44.88	
156	Wellfleet, Great Island Meadows.	3	Pebbles, . .	Exposed.	1.024	9.17	145	5	15.66	26.55	35.41	42.84	49.23	
157	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	5.64	83	5	11.18	17.95	24.36	30.05	35.13	
158	Wellfleet, Great Island Meadows.	3	Sand, . .	Exposed.	1.024	3.95	56	5	9.14	13.57	18.33	22.78	26.91	
159	Wellfleet, Great Island Meadows.	3	Sand, .	Exposed.	1.024	5.92	88	5	11.53	18.66	25.30	31.18	36.41	
160	Wellfleet, Great Island Meadows.	3	Sand, .	Exposed.	1.024	3.38	47	5	8.53	12.32	16.38	20.32	23.99	
161	Wellfleet, south of Lieutenant's Island.	2	Sand, . .	Exposed.	1.024	5.78	65	5	11.36	18.31	24.83	30.61	35.77	
162	Wellfleet, south of Lieutenant's Island.	2	Sand, . .	Exposed.	1.024	2.12	29	5	7.07	9.31	11.74	14.27	16.80	
163	Wellfleet, south of Lieutenant's Island.	2	Sand, . .	Exposed.	1.024	2.12	29	5	7.07	9.31	11.74	14.27	16.80	
164	Wellfleet, south of Lieutenant's Island.	2	Sand, . .	Exposed.	1.024	4.24	60	5	9.49	14.34	19.42	24.11	28.42	

165	Wellfleet, north of Egg Island.	5	Sand, . .	Exposed.	1.024	14.59	266	5	22.00	37.42	48.78	57.82	65.20	
166	Wellfleet, north of Egg Island.	4	Sand, . .	Exposed.	1.024	7.68	118	5	13.78	23.03	30.99	37.79	43.71	
167	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	12.69	218	5	19.69	33.74	44.38	52.97	60.15	
168	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	12.06	203	5	19.05	32.51	42.88	51.29	58.37	
169	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	9.31	147	5	15.84	26.84	35.79	43.27	49.70	
170	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	11.07	182	5	17.90	30.49	40.41	48.52	55.41	
171	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	11.35	188	5	18.23	31.06	41.11	49.30	56.25	
172	Wellfleet, Egg Island, .	5	Coarse sand, .	Exposed.	1.024	9.38	150	5	15.92	26.99	35.97	43.49	49.93	
173	Wellfleet, Egg Island, .	5	Coarss sand, .	Exposed.	1.024	10.15	163	5	16.83	28.60	38.02	45.83	52.51	
174	Wellfleet, Egg Island,	5	Coarse sand, .	Expossd.	1.024	11.91	200	5	18.88	32.21	42.51	50.88	57.93	
175	Wellfleet, Egg Island,	5	Coarse sand, .	Exposed.	1.024	8.04	124	5	14.23	23.91	32.15	39.10	45.16	
176	Wellfleet, Sow Rock Bar, .	5	Coarse sand, .	Exposed.	1.024	5.15	75	5	10.58	15.73	22.71	28.07	32.90	High bsd.
177	Monomoy, raft, . .	4	Coarse sand, .	5.0	1.024	19.95	422	5	28.24	46.89	59.75	69.36	76.55	Sand box.
178	Wellfleet, south of Lieutenant's Island.	2	Sandy mud, .	Exposed.	1.024	2.89	40	5	8.00	11.22	14.66	18.13	21.39	Eelgrass.
179	Wellfleet, south of Lieutenant's Island.	2	Sandy mud, .	Exposed.	1.024	2.54	35	5	7.58	10.35	13.34	16.38	19.30	
180	Wellfleet, south of Great Beach Hill.	1	Sand, . .	Exposed.	1.024	.85	11	5	5.76	6.57	7.42	8.33	9.27	High bed.
181	Wellfleet, south of Great Beach Hill.	1	Sand, . .	Expossd.	1.024	.99	13	5	5.88	6.83	7.84	8.91	10.02	High bed.
182	Wellfleet, south of Great Beach Hill.	1	Sand, . .	Expossd.	1.024	.21	3	5	5.19	5.39	5.60	5.81	6.04	High bed.
183	Wellfleet, south of Great Beach Hill.	1	Sand, . .	Exposed.	1.024	.56	7	5	5.50	6.03	6.59	7.19	7.71	High bed.
184	Wellfleet, east of Great Beach Hill.	3	Gravel, . .	Exposed.	1.024	2.54	35	5	7.58	10.35	13.34	16.38	19.30	Nsar shore.
185	Wellfleet, east of Great Beach Hill.	3	Sand, . .	Exposed.	1.024	2.75	38	5	7.83	10.87	14.14	17.42	20.55	Near shore.
186	Plymouth Harbor, Egobert's Flat.	4	Fine sand, .	Expossd.	1.021	11.73	197	5	18.67	31.84	42.06	50.37	57.39	
187	Plymouth Harbor, Egobert's Flat.	4	Fine sand, .	Exposed.	1.021	7.43	113	5	13.45	22.41	30.18	35.86	42.70	Eelgrass.

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During the past four years the investigations at Wellfleet were carried on to determine the practicability of securing a "catch of oyster spat" in Wellfleet Bay. The catching of spat is a very important advantage to the oyster industry.

The report of Mr. Belding follows: —

OBSERVATIONS ON THE SET OF OYSTER SPAT IN WELLFLEET BAY.

The future success of the Massachusetts oyster industry will depend not only upon producing oysters of good quality and accessible markets, but also upon the raising of seed oysters. At the present time the problem of obtaining small oysters is an important factor in the development of the industry, since the greater part of the seed is brought from Long Island Sound, the Massachusetts oysterman paying the added cost of transportation. By raising native seed other difficulties, such as the inability to obtain suitably small oysters for planting and the prohibitive prices in years of poor set in Long Island Sound, will be eliminated, and the oyster industry in the Commonwealth placed on a more substantial basis.

Owing to variable natural conditions the control of the oyster set, in spite of numerous investigations in this country and abroad, has proved a baffling problem, which, possibly, may never be satisfactorily solved. At the present time young oysters can be caught, with more or less uncertainty, by placing shells in the water during the spawning season, the planter having no means of foretelling whether he will get a good or a poor set. Except in Buzzard's Bay and the Taunton River, where there were once natural oyster beds, little attempt has been made to catch the natural set, the Cape Cod planters obtaining their seed outside the Commonwealth. The object of this paper is to present a few facts concerning spat collecting, with the hope that it may arouse renewed interest in the production of native oyster seed. The following observations in Wellfleet Bay, in spite of their limited scope, show that oyster spat can be collected artificially in localities commonly considered unproductive, and that similar results can be obtained in other sections where spat collecting has not been given a fair trial by the oystermen.

The following report consists of an introductory section, briefly dealing with the natural history of the oyster in as far as it relates to general spat collecting, a description of the conditions in Wellfleet Bay, and the results obtained from an investigation of the spawning season and from experiments with spat collectors. The methods of work are described under each topic.

Natural History.

Spawning. — The American oyster (*Ostrea virginica*) is unisexual, whereas the European species (*Ostrea edulis*) is hermaphroditic, *i.e.*, both sexes occur in the same animal. The ripe generative organs (Fig. 62), in either sex, surround the liver and intestine, giving the appearance of branching veins filled with creamy white contents. The eggs or spermatozoa, during the act of spawning, are extruded from

two main ducts, opening, one on each side, below the large adductor muscle, and are swept from the mantle chamber into the water, where they unite with the spawn from another oyster of the opposite sex. The oyster ready to spawn is popularly said to be "in milk," owing to the white, milky appearance of the reproductive organs. In Massachusetts waters the oyster begins to spawn at the age of two years, but its greatest activity does not take place before the fourth or fifth year.

Fecundation. — According to the late Prof. W. K. Brooks of Johns Hopkins University the average female oyster is capable of producing 16,000,000 eggs per season. The extruded eggs, about 1/400 of an inch in diameter, can be seen by the naked eye as tiny white specks, which under the microscope have a round opaque appearance, due to the yolk granules within the cell. The spawn of the male oyster has a uniform milky consistency, due to the great number of minute spermatozoa, which mainly consist of a nucleated body and long slender tail. In this way nature has provided a division of labor, since the egg is the inactive form, which contains the nutriment, while the spermatozoön is modified for swimming in search of the egg.

In order that the egg, which has been cast off from the parent oyster, shall develop into a new individual, it must unite with a spermatozoön, the act of fusion being known as fecundation or fertilization. In nature the meeting of these two is often a matter of chance, depending upon the simultaneous spawning of several oysters in the same locality, and probably numbers of eggs are never fertilized.

Early Life History. — With the completion of spawning the adult oysters have fulfilled their parental duties and the developing embryo is at the mercy of the natural elements. In order to overcome such adverse conditions as sudden changes in temperature, cold rains, storms, freshets, as well as the active enemies of the young larvæ, and in order to maintain the proper equilibrium in spite of this great destruction, nature has provided an enormous number of eggs for every female oyster.

During the first few hours, if the temperature of the water is not below 70° F., the embryo develops by the usual method of unequal cell division, and passes successively through 2, 4, 8, 16, 32, etc., celled stages, until it finally becomes a mass of small cells surrounding a few large cells, which are to form the primitive digestive tract. In the course of a few hours these surface cells throw out fine hair-like processes, cilia, which by their lashing enable the animal first to rotate and then to swim through the water. The body soon elongates; cilia are only visible on the front end; the primitive mouth is formed on the under surface; and the shell gland is developed opposite the mouth. Gradually a thin, transparent shell envelops the body, the cilia on the anterior end forming a thick pad, the velum or swimming organ, which permits the little shelled larva to lead a free-swimming existence.

The formation of a mouth, stomach, intestine and anus enable the young animal to digest minute organisms and to obtain its sustenance from the water. During this veliger period the oyster larvæ can readily be taken by towings with the plankton net.

Attachment. — About the sixth day, the length of the free-swimming period depending upon the temperature of the water, the embryo settles to the bottom, and, if fortunate, attaches itself to some hard clean surface by the edges of the mantle, a fleshy fold on the inside of the shell. This temporary attachment is soon replaced by a calcareous fixation which firmly fastens the oyster by its left or deep valve to the object of support. The attachment is caused by a sticky secretion from the mantle which becomes impregnated with lime salts. Several instances have been observed on the gravel bar in Herring River, Wellfleet, where yearling oysters had made a second attachment at the edge of the shell, leaving an interval between the two pebbles (Fig. 68: 16). This fact indicates that the oyster at the age of one year still retains its power of attachment.

Previous to the attachment the early straight-hinged veliger larva has changed in size and shape to an unequivalvular form, with prominent umbones pointing posteriorly, which is readily recognizable under the microscope. During the early attachment period the anterior adductor muscle disappears, the gill filaments increase in number, and a different shell formation takes place.

Spat Collecting.

The present system of spat collecting developed from a study of the attachment habit in the young oyster, the planters finding that they could aid nature during the spawning season by placing in the water suitable objects on which the larvæ would set. The oyster will fasten to any hard clean surface, often on unusual objects, as old shoes, rubber boots, tin cans, clay pipes, glass bottles, and many other articles which occasionally find their way into the water. At Monomoy Point a large lobster was captured with five oysters, two and one-half months old, attached to its shell.

In America various shells have been utilized for cultch. In Massachusetts the oyster shell, most popular in other States, is generally considered second to the scallop, which, of a more fragile nature, readily allows the breaking apart of the clustered oysters. The heavier oyster shell does not break as easily, and consequently, unless the clusters are separated by hand, the oysters either die or take on an elongate form from lateral pressure. Oyster shells are preferred for exposed waters, scallop for quiet localities where the light shells will not be washed away. Clam, mussel, razor clam, silver or jingle shells, as well as gravel and small stones, are occasionally used. In Europe intensive oyster culture demands more elaborate methods, and various

combinations of brush, bamboo, rope, tile and cement are used to catch the spat.

In the United States spat is collected both in the deep water and beween the tide lines. The former method is used in Long Island Sound, where the cultch is planted in water as deep as 40 feet; the latter in Massachusetts, where the seed is taken mostly between the tide lines (Fig. 64). The waters at the head of Buzzard's Bay, formerly the site of several natural oyster beds, yield an abundant harvest from the planting of shells on the gravel bars in brackish water. Outside of Buzzard's Bay and Narragansett Bay little spat collecting is carried on in Massachusetts, the planters preferring to buy their seed outside the State.

In placing the spat collectors the planter should have in mind two things: first, the desirability of a hard bottom to support the shells; secondly, the danger of planting the shells too early. In certain cases it is profitable to artificially harden the bottom with stones or gravel before planting. After the shells have been in the water for a short time, they become covered with a slimy growth of microscopic plants, which renders impossible the attachment of the young oyster. For this reason, except in favored localities, where the growth of the slime is slow, the oysterman must needs wait until the spawning season is well under way before placing his shells in the water. Even then the conditions determining a set are so erratic that the oysterman does not average more than one good set in every three to four years.

In Massachusetts the oyster industry is regulated locally by the various coast towns, and spat collecting is permitted under the following conditions:—

> The mayor and aldermen of a city or selectmen of a town may, by writing under their hands, grant a license for a term not exceeding ten years to any inhabitant thereof . . . to plant oyster shells for the purpose of catching oyster seed, upon and in any waters, flats and creeks therein, at any place where there is no natural oyster bed; not, however, impairing the private rights of any person, nor materially obstructing any navigable waters. . . . The shore line of such licensed premises shall be . . . the line of high water for the planting of oyster shells, but the provisions of this section shall not authorize the placing of such shells upon the land of a riparian owner between high and low water mark without his written consent.

Conditions in Wellfleet Bay.

During the summer of 1908 a series of observations was made upon the oyster set in Wellfleet Bay. In this locality the planters, after a few unsuccessful attempts, had gradually reached the conviction that the capture of oyster spat in Wellfleet Bay was almost an impossibility. With the object of possibly discovering a remedy for this condition, the following plan of investigation was outlined: (1) a survey

of the natural oyster set in the bay; (2) observations on the spawning and larvæ in the water; (3) experiments with spat collectors in the different parts of the Bay.

Wellfleet Bay. — Wellfleet Bay, an arm of Cape Cod Bay some 4 miles long and 2 miles wide, has an extensive area of flats, owing to the great rise and fall of the tide (10¾ feet). For this reason practically all the set is found between the tide lines, although spat is occasionally noticed on the oysters planted in the deep water. The flats vary in composition from gravel to soft mud, but for the most part consist of a dark coarse sand. The tide flows swiftly, causing a slight shifting of the flats, especially in the lower part of the bay, and forming numerous sand and gravel bars, such as Stony, Smalley's, Blackfish Creek and Herring River bars. At the head of the bay, on the east and west sides, are two inlets, Duck Creek and Herring River, while half way down on the east side is Blackfish Creek. At low tide little remains of these tributaries except streams in the channel bed. The two principal sand bars are Smalley's Bar, opposite Blackfish Creek, and Egg Island, at the northern end of the bay.

The Wellfleet Oyster Industry. — In any consideration of the set it is essential to know the amount of adult spawning oysters on the beds. In 1908, when the greater part of our observations were made, there were but 70,000 bushels of oysters planted in the bay. Of this number, 68,000 were three-year-old oysters, the remainder seed. Five and six-year-old oysters were found in scattering quantities near Indian Neck, in the northern part of the harbor. In spite of the small number and size of the spawning oysters a comparatively heavy set occurred in 1908, which indicates that favorable weather conditions during the spawning season are more important than the number of spawners. In 1909 approximately the same number of oysters were on the beds, but being older were capable of producing more spawn. In 1910 and 1911, owing to the development of the Wellfleet industry by new companies, a considerably larger number of oysters were planted.

Previous Attempts at Spat Collecting. — The first settlers in Wellfleet found a natural oyster bed in the vicinity of Hitchin's Creek or Silver Spring in 1644. In 1775 this natural bed was completely destroyed and was never replenished, owing to the lack of suitable objects on which the spat could catch. Until 1908 the only successful spat collecting had been in Herring River, where two set, the last in 1906, had been obtained by Mr. E. P. Cook of Wellfleet. Various attempts have been made in other parts of the bay by the oystermen, with indifferent success.

Preliminary Survey. — The main problem was to determine whether the prevailing opinion that unfavorable natural conditions rendered spat collecting impossible was true or whether it had arisen through lack of initiative and erroneous methods. The first step in the solution of

this problem was a general survey of the oyster set of previous years in order to determine the most productive localities. For this purpose an examination of the rocks, gravel bars, wharf pilings, stakes, etc., was made for evidences of set.

The result of the survey indicated that artificial spat collecting could be carried on successfully, as was later substantiated by the experimental collectors. The observations were briefly as follows: —

(1) The greater part of the oyster set took place between the tide lines, which limited the area for placing the experimental spat collectors.

(2) Sufficient evidence was found of the natural abundance of larvæ in the water, as in the favorable localities whenever a clean surface was presented a few spat could be found attached, the chief difficulty being the lack of suitably raised collectors. The number of oysters from one to three years old, attached to the piling and stones under Commercial and Chequesset Inn wharves (Fig. 66), as well as the quantity of living and dead oysters on the stones, pebbles and large rocks in nearly every part of the bay, gave promise of an abundant natural production.

(3) The localities of the greatest natural set appeared to be Herring River, Blackfish Creek and the bar south of Jeremy's Point, locally known as Stony Bar.

The Plankton Net.

The importance of determining the spawning season and time of set in Wellfleet Bay was early evident, since such information not only would show the proper time to put down our spat collectors, but also, when continued through a series of years, would prove of value to the local oyster planters. For this reason the first step in our investigation was directed toward a study of the spawning habits of the oyster in this locality.

Methods of Investigation. — Beginning in May examinations were made at definite intervals to determine the condition of the spawn in the adult oysters on the grants. Information was also gathered from the oystermen as to when the oysters were "in milk," and at what times in previous years spat had been observed, a method which, although helpful, did not give as definite results as the plankton net, and which, after 1908, was used only for general reference.

The general usefulness of the plankton net, which has been used extensively in the study of microscopic life in the water, suggested that it might prove of value in determining the presence of the free-swimming oyster larvæ previous to the time of set. In the past little attention has been given to the shellfish larvæ in the veliger or free-swimming stage, and merely the abundance or scarcity of any year noted. An endeavor was made to make our work roughly quantitative

by using stated distances, same period of tide and a uniform method of counting the larvæ with the microscope and Rafter cell.

The tow net was made of No. 11 silk bolting cloth, supported from a copper ring 12 inches in diameter by a fold of canvas. The net was towed behind a dory near the surface of the water at a uniform rate of speed, which permitted the water to filter through the fine meshes, leaving the plankton or floating organisms. A uniform speed was essential, as too rapid movement would result in the backing of water from the net, owing to the difficulty of filtering, and too slow a rate would allow the net to sink. The variation in current, tide and wind likewise rendered difficult the filtration of the same amount of water at each towing, so that the counting was only roughly comparable. Except in protected inlets any quantitative work with a simple net in sea water necessarily has to allow for these errors. As the same distance, a round trip of 600 feet off Chequesset Inn wharf, was taken for each towing, and only approximate results desired, the value of the work from a practical standpoint was little affected.

The second step was the separation of the oyster and other shellfish larvæ from the miscellaneous plankton forms in the towing, which had been washed into a small pail containing about 3 inches of water. The water was given a whirling motion with a small stick, which forced the larvæ by centripetal action to the center of the pail, where they could be easily taken out with a pipette. The operation was repeated several times to obtain all the larvæ. If, perchance, sand had been taken in the towing, it would also settle to the center with the lamellibranch and gasteropod larvæ, but the larger grains could be separated later by proper manipulation in small glass dishes. No satisfactory method of separating the fine sand grains or gasteropod larvæ from the lamellibranch veligers could be devised, except the laborious method of picking out the individuals with a fine pipette. However, their removal was not essential, since they did not materially interfere with the counting.

The method of counting is an adaptation of the Sedgwick-Rafter device for counting diatoms and algæ. The larvæ are spread evenly in a Rafter cell, consisting of a brass rectangle, 1 millimeter high, 20 millimeters wide and 50 millimeters long, fitted onto a glass slide and having a volume of 1,000 cubic millimeters, or 1 cubic centimeter. By means of a ruled square in the ocular of the microscope, covering 1 square millimeter of surface on the slide, the larvæ are counted from ten different areas and the result multiplied by 100 to give the entire number, which, if the distribution in the cell is even, proves a fair estimate.

Results.

The Oyster Larva. — The duration of the veliger or free-swimming period is variable, the temperature of the water having a great influence on the rapidity of larval development. During this stage certain

anatomical changes occur which render the animal capable of forsaking the free-swimming existence and ready to lead a stationary life. It is difficult to distinguish the oyster from the other shellfish at this period, the early veligers of many lamellibranchs having the same flat hinge line. It is only during the last days of the veliger stage that the final characteristics which differentiate it from the quahaug, clam, scallop and other shellfish appear. The oyster just previous to the time of set has an equi-valvular shell with projecting umbones (beak) pointing posteriorly. The convex left valve is larger than the right and forms the greater part of the characteristic hump-like umbones.

The appearance in the towings of the larva with prominent umbones marks the time for immediately putting down the shell spat collectors. Recognition of the young oyster at this period by the plankton net and microscope should prove of value to the oyster planters, especially in the localities where the natural conditions, favorable for the growth of minute animal and vegetable life in the water, render a short submergence of the shells imperative. In Buzzard's Bay the oysterman considers it important to know the exact time of set in order to prevent his shells becoming covered with a slime, which would interfere with the attachment of the spat. In this respect conditions are more favorable at Wellfleet, the shells sliming but little. It is to be regretted that our method of determining the exact time of set, since it depends upon microscopical examination of the larval oysters, cannot become of popular use among the practical oystermen of the Commonwealth.

The Spawning Season. — In Wellfleet Bay the spawning season approximately extends from the middle of June to the middle of August; but the greater part of the spawn is liberated during the last week in June and the first two weeks in July. The actual spawning of the individual oyster is probably of brief duration, and the long season is best explained by the variation in the ripening of the different oysters. Observations of the spawning season for four years gave the following data: in 1908 microscopical examinations of the eggs showed that a few oysters had begun to spawn as early as June 12, but that the season practically did not start until June 23; by July 10 the majority of oysters in the upper part of the bay had ceased spawning, while the oysters in the lower part, where the water was cooler, were not so far advanced. In 1909 the main spawning took place between June 26 and July 10, followed by a second period between July 22 and July 31. In 1910 the first spawning occurred between June 24 and July 1, the second from July 13 to July 22, and scattering larvæ were found in the water from July 27 to August 12. In 1911 the first spawning came between June 28 and July 5, the second from July 19 to July 22, and scattering larvæ were found from July 26 to August 24. According to these records the principal spawning takes place during the last week in June and the first two weeks in July, with a slight

variation for the different years. The subsequent spawning evidently depends upon variable temperature conditions, and exhibits no regularity.

Temperature and Spawning. — The temperature of the water was the chief factor regulating the spawning, which took place at 70° F. or over. The 1911 season was slightly later than 1909 and 1910, owing to the cold weather during June. The temperature of the water in the upper part of Wellfleet Bay followed closely the weather changes, the action of the sun on the flats exposed at low tide rapidly raising the temperature several degrees. The sudden bursts of spawning were invariably preceded by a high temperature of the water, brought on by the hot weather, the month of July, during which most of the spawning took place, averaging 3 degrees warmer than the month of August. In general, the time of spawning could be told from the condition of the weather and the temperature of the water, the observant oysterman invariably predicting an early or late season.

The Destruction of Larvæ. — The numerous offspring of the oyster maintain a continuous struggle for existence against the adverse forces of nature. In our study with the plankton net a few observations were made on the effect of cold rains upon the larval oyster and other shellfish. In most cases the rain either caused the destruction of the swimming larvæ or forced them to settle to the bottom. At Monomoy Point, Mass., during a long, cold rain, counts were made of the number of larvæ in a certain amount of water which passed through the plankton net: before the rain, 30,000; after nine hours, 15,000; after fifteen hours, 3,000. After the rain ceased the number of larvæ gradually increased, until it was the same as at the first counting.

The years of the best set have had little or no rain during the brief free-swimming period, thus affording no drawback to the development of the larva. The conditions causing set are varied, complex and constantly changing. A set is achieved by a happy combination of favorable conditions largely presided over by the element of chance, and for this reason will always remain a more or less baffling problem to the oysterman, who in his feeble way is unable to control the mighty forces of nature.

Spat-collecting Experiments.

In connection with the use of the plankton net small shell collectors were put down in order to determine the values of the different parts of the bay and to ascertain the natural conditions influencing spat collecting. Seventy-four collectors, consisting of ½ to 1 bushel of shells, were placed between the tide lines in the selected localities, and covered with galvanized wire netting, 1-inch mesh, securely fastened to the flat by four short stakes, in order to prevent the contents from washing away in the strong currents. The final result showed a little mound of shells, 6 to 8 inches high, covering perhaps 5 square feet. By this simple device it was possible at a small expense to test a large

territory with more satisfactory results than by using a few large collectors. In studying any particularly favorable locality, such as a sand or gravel bar, a series of collectors were placed at definite intervals to determine the most favorable part.

Three difficulties which unfavorably influenced the results were encountered: (1) the shells were difficult to obtain and the greater part of the collectors consisted of razor clam shells, a form less suitable for catching spat than the scallop or the oyster shell; (2) the extreme lowness of the shell heaps, not over 8 inches above the surface of the flat, rendered the small collectors less efficient than larger heaps; (3) part of the collectors were planted late in the spawning season, July 11 to July 24, and possibly may have missed the heavier part of the set. They were taken up September 7 to October 14, the more important being taken up first. By this time the young oysters were of a readily discernible size.

Location of the Collectors. — Seventy-four collectors were placed between the tide lines around the bay, from Billingsgate Island on the west to the south side of Lieutenant's Island on the east, a distance of nearly 7 miles. In Herring River and Blackfish Creek were long, tongue-shaped bars over which the tide flows swiftly. On these a series of collectors from high to low water mark were set out to find at what depth of water the greatest abundance of set occurred. A second series at right angles to the first were placed across the bar in the direction of the tide flow, to determine whether the set took place on the outer edge, mid surface or inner edge of the bar. In the other parts of the bay the more isolated collectors were usually placed in pairs, one near high, the other near low water mark.

Results. — Of the 74 collectors, 26 were washed away, the greatest loss taking place in Blackfish Creek, near the Chequesset Inn and Egg Island, Jeremy's Point and Billingsgate Island. The condition of the remaining 48 can be classified as follows: (1) good, 14, mostly in Herring River and Blackfish Creek; (2) fair, 18; (3) poor, 16. Only in one place were the collectors a decided disappointment, on the north side of Blackfish Creek, where the entire bar shifted with the early autumn gales, either burying or washing away the small shell heaps.

When taken up only 18 collectors out of the 48 which were recovered had caught any spat. The following table gives location, the number of collectors, the percentage of shells found and the relative value of the locality in terms of the amount of spat. The collector with the greatest number of young oysters was takén as the standard and given 400 per cent. Since a collector which contained 10 per cent. of the original shells could not capture as much spat as one with 50 per cent., it was necessary, in determining the relative value of the locality, to allow for this difference by estimating the catch for the entire collector.

Location.	Number of Collectors.	Per Cent. of Shells.	Value (Per Cent.).
East side of Great Island, ...	1	25	2.67
East side of Great Island, ...	2	25	5.33
Herring River, ...	3	33	6.00
Herring River, . . .	4	25	400.00
Herring River, ...	5	25	266.67
Herring River, ...	6	25	8.00
Herring River, ...	7	25	5.33
Herring River, ...	8	25	10.67
Herring River, . . .	9	25	2.67
Herring River, ...	10	25	5.33
Herring River, . .	11	10	33.33
Indian Neck, ...	12	10	6.67
Indian Neck, ...	13	10	6.67
Blackfish Creek, ...	14	10	6.67
Blackfish Creek, ...	15	40	5.00
Blackfish Creek, ...	16	40	6.67
Blackfish Creek, ...	17	40	41.67
Blackfish Creek, ...	18	10	13.33

(1) *At what Level between the Tide Lines does the Best Set occur.* — The greater part of the set in Wellfleet Bay occurred between the tide lines, which was due in some measure to the height of the tide, 10¾ feet, and the large area of exposed flats. To determine at what height the set of oysters was most likely to take place, three classifications of the collectors were made, (1) *high,* (2) *medium,* and (3) *low,* according to their situation in regard to low-water mark. Of 47 collectors, 17 were high, 9 low and 21 medium. Of the 18 collectors which caught set, 3 were high, 13 medium and 2 low, showing a per cent. of 72 for the medium in the productive collectors as compared with 45 of the total number. The strip of territory about half way between the tide lines in Wellfleet Bay was the most productive of oyster seed, and recognition of this fact should be taken by the local oyster planters in putting down shells for spat collecting.

(2) *Gravel Bars as Natural Spat Collectors.* — When a long bar projects from the land at the mouth or entrance of a bay, creek or river, it seems to act as a natural spat collector for shellfish, particularly oysters, if there are suitable objects, such as shells or pebbles, on which the set can fasten. The top or highest portion of the bar seems most suitable for the attachment of the young oyster, while the clams and quahaugs are deposited around the edges. It is especially noteworthy

that in Wellfleet Bay the best grounds for the oyster set are the raised bars swept by the tidal currents in Herring River and Blackfish Creek.

(3) *Artificial Bars.* — The preliminary survey showed that the chief difficulty in obtaining oyster set in Wellfleet Bay was due to a lack of raised places for catching the seed. The question then arose as to whether portions of the ordinary flats could not be modified in some manner to afford suitable collecting ground. The problem of raising the level of the chosen locality to make a firm foundation for the shells was considered, and in order to test the efficiency of this plan an unproductive flat of soft mud in Herring River was selected. Several loads of coarse gravel were dumped upon the soft mud until a solid raised platform was built. On this the shell collectors were placed. If the shells had been placed on the mud before it had been covered with the gravel they would soon have been covered with silt. A fair set was obtained on the shells, which proved that by proper means many places on the flats of Wellfleet Bay could be utilized in a similar manner.

The Survey.

About Dec. 1, 1908, a record was taken of the natural conditions in the localities of abundant set and a general survey was made for the purpose of determining the favorable locations of the set in the various parts of the bay, on the bars, flats and large rocks.

The West Side of the Bay. — Passing north from Billingsgate Island the first locality of set was the low gravel bar, locally known as Stony Bar, situated south of Jeremy's Point. The tide passed with great swiftness over the bar, which was exposed only at extremely low running tides, rendering this locality, in spite of its favorable location for an abundant oyster and quahaug set, unsuitable for artificial spat collectors. Here quantities of small oysters were found attached to the gravel and small stones.

The tidal flats on the bay shore of Great Island consisted mostly of yellow or dark colored sand, furnishing no foundation for the set except on the large rocks which were scattered along the shore. Occasionally stones or pebbles covered with small oysters averaging 19 millimeters (4/5 of an inch) in size were gathered. North of the "Meadows," a gravel bed, 40 by 30 feet was covered with a thick set, averaging 14.8 millimeters (3/5 of an inch). The scattering set from this locality to Herring River averaged slightly larger, abont 22 millimeters (5/6 of an inch).

The North Side of the Bay. — With the exception of Herring River, which will be described later, the north side showed a similar condition, — a scattering set on the pebbles and stones; but, owing to the greater amount of suitable objects for fixation, the natural set was correspondingly greater. The average size along this shore was 22 millimeters (5/6 of an inch). The heaviest set was found on the wooden piles and rocks under the Chequesset Inn and Commercial wharves, which were

literally covered with young oysters, averaging 20.48 millimeters. Likewise the stakes marking the quahaug beds proved miniature collectors, a single stick often holding as many as 50 spat.

The East Side of the Bay. — The same conditions held true along the entire east shore, a scattering set on all stones and shells exposed from the sand. The rocks on Indian Neck and the west side of Lieutenant's Island were well supplied with spat. On the south side of Blackfish Creek a gravel bar extending from the shore of Lieutenant's Island in a northerly direction proved one of the best situations in the bay for planting shells. The abundance of the natural set and the results from the experimental spat collectors showed that this region ranked next to Herring River in the production of seed oysters. The average size, 13 millimeters (1/2 inch), was less than in the upper part of the harbor.

The Rocks. — A number of rocks, varying in size from small stones to a circumference of 70 feet, were scattered over the flats along the eastern and western shores. These rocks often occurred in clusters or groups, as at Indian Neck or west of Lieutenant's Island; but occasionally solitary specimens rose abruptly from the sands. The larger of the rocks, known to the quahaug fishermen as Old Sow, Blue Rock, etc., furnished evidence of an abundant natural set, and indicated what might be accomplished, by proper spat collectors, since, with few exceptions, their sides, 2 feet above the sand, were thickly covered with oyster spat. In many instances the young oysters had attached to a previous set and could be readily scraped off the rocks.

On the western side of the bay records were taken of the oyster set on six rocks from 2 to 9 feet in diameter. The average number of oysters per square foot was 41, ranging from 28 to 80, and the average size 12.23 millimeters (1/2 inch).

Blue Rock, the largest in the bay, having a circumference of 70 feet and rising 12 feet above the sand flat west of Lieutenant's Island, had the heaviest set. The rock lies in a favorable location and is completely covered only during the high course tides. The 1908 set began 1 foot from the bottom, was thickest from 1 to 4 feet and gradually thinned from 4 to 6 feet. The different sides showed variations in the amount of set: the west side averaged 125 per square foot, size, 9.84 millimeters; the east side, 109, size, 6.96 millimeters; the south side, 125, size 10 millimeters; the north side, 53, size, 9.44 millimeters. The size of the set on the small rocks near by varied from 8 to 15.5 millimeters, according to location.

Herring River. — Herring River emptied into the northwest corner of the bay by a deep bend which almost separated Great Island from the main land. Formerly the incoming tide passed swiftly up the river to flood thousands of acres of salt marsh along its numerous branches; but in 1909 the passage of salt water above the first bend was prevented by the construction of a dike. The area concerned in the oyster set lay below the dike, and although the river currents were

somewhat altered, the conditions governing the set in this territory remained unimpaired by the construction of the dike.

Scattering oysters were found on the stones, shells and sedge along the shores. In one instance the projecting sides of a gunning tub, buried in the sedge, had caught 75 spat 15 millimeters in size. Two principal localities of set were found: on the north side of the river were the remains of an old wharf, used in former days for the fishing schooners. Here the old piles and stones were covered with oysters; but owing to the absence of suitable objects for attachment outside the wharf little set was noticeable.

The second locality was a gravel bar on the south side of the river, which proved the best spat collecting territory in the bay. This bar, covering approximately 500 by 150 feet, ran in a northwesterly direction from a point on the north side of Great Island in such a manner that the incoming tide flowed over it diagonally. Between the outer side of the bar and the channel at low tide was an area of shifting sand, while on the south and west a sand and mud flat separated it from Great Island. A series of spat collectors on this bar gave excellent results. The scattering shells, placed on the gravel area by Mr. E. P. Cook of Wellfleet also received a good uniform set. Over this bar 6 shells, averaging per shell 11.5 spat, 18.5 millimeters in size, were found to the square foot.

The great abundance of the set is due to the location of the bar in reference to the natural conditions of current, tide and shore line. The bar presents (1) a peculiar shore formation, guiding the flow of the tidal currents; (2) a high raised surface; (3) heavy material, such as gravel and pebbles, which offer a suitable foundation for the shells as well as serving as spat collectors; (4) the direction and force of the current, which has full sweep over the bar, affording a chance for the floating larva at the proper time to come in contact with suitable objects for attachment.

Conclusions.

(1) The idea of the Wellfleet oystermen that the capture of seed in Wellfleet harbor was impossible has proved erroneous. Our experiments have demonstrated that spat can be successfully gathered if the oystermen will use intelligent perseverance.

(2) At present there is an abundance of natural spat in the waters, but a lack of suitable objects on which it can set. The heavy sets on the gravel bars, rocks and under the wharves are obvious evidence.

(3) The two localities where set is most certain at the present time are the gravel bars in Herring River and Blackfish Creek.

(4) Other localities, particularly on the north end of the bay, can be made productive of oyster set by the formation of artificially raised gravel bars on which to plant the shells.

(5) The set takes place between the tide lines, only a small part striking in the deep water. The heaviest set is about half tide line.

(6) The spawning season lasts from June 15 to August 15, but the principal spawning takes place during the last week in June and the first two weeks in July.

(7) A method of determining by microscopical examination the exact time of oyster set has been tried with success. This is important to the oysterman in deciding at what period he should put down his shells to prevent sliming.

(8) The shell collectors in Wellfleet Bay gather slime slowly, due in part to the long exposure of the flats to the sun and air. Ordinarily the Wellfleet oysterman should put down his shells during the first week in July.

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ILLUSTRATIONS

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Fig. 3. — Egg, twenty-five minutes after fecundation, showing the two polar cells (pc) and the faintly developed yolk lobe. Magnified 385 diameters.

Fig. 4. — Egg just previous to the first cleavage, showing large yolk lobe. Magnified 385 diameters.

Fig. 5. — The two-celled stage at the completion of the first cleavage, fifty minutes after fecundation. The larger cell contains the yolk lobe. Magnified 385 diameters.

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Fig. 14. — The thirty-two-celled stage, two hundred minutes after fecundation. Side view. Note large yolk cell. Magnified 385 diameters.

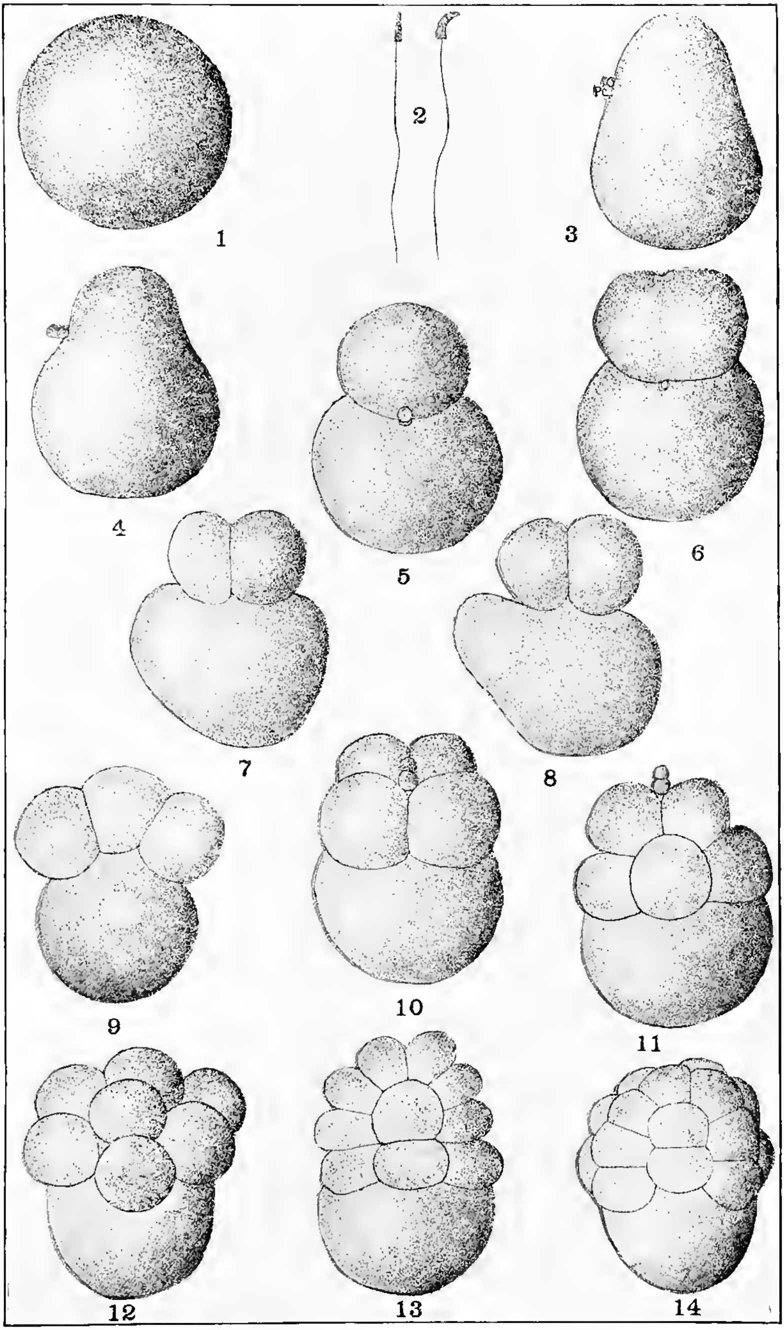
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Fig. 15. — Ciliated gastrula, ten hours after fecundation. The embryo can now swim through the water by means of hairlike cilia. The larger cells have become invaginated. Magnified 385 diameters.

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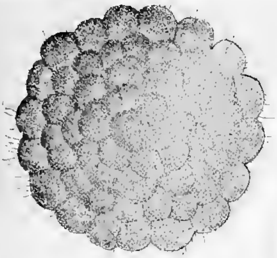
Fig. 18. — Early veliger swimming with velum extended from the shell, about thirty-six hours after fecundation. aa, anterior adductor muscle, pa, posterior adductor muscle, s, stomach, a, anus, mt, mouth, v, velum. Magnified 385 diameters.

Fig. 19. — Veliger slightly older than shown in Fig. 18. The intestine (i) has elongated, and the liver (l) is more prominent.

Figs. 20-27. — Figs. 20–24 illustrate the ordinary method of crawling of the small 2 to 3 millimeter quahaugs. It consists of extending the foot and dragging the body in a forward direction. Fig. 20 shows the foot just appearing from the shell; the mantle and siphon are extended, while the angle between the shell and the foot is acute. Fig. 21 shows the foot extended to its full length. It has made a twist so that the bottom part of the ciliated tip can get a firm hold, and thus raise the animal on edge so that the shell can enter the sand with a cutting edge. In Fig. 22 the shell has taken a downward tip, the foot being partly withdrawn into the shell. Fig. 23 shows the animal at the completion of an upward tip, caused by the further withdrawal of the foot, which has straightened the shell into its original position. Figs. 24 and 27 show another method of crawling, the quahaug being forced backward by a forceful movement of the foot. In Figs. 24 and 26 the foot is turned under the shell until the tip finds a resting place; then by a jerky motion the shell is raised from the bottom and thrust either to the position of Fig. 25 on the same side or turned over on the opposite side (Fig. 27).



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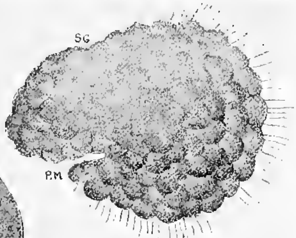

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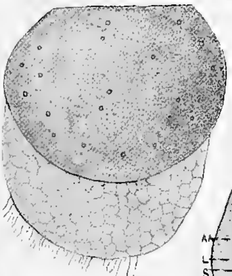

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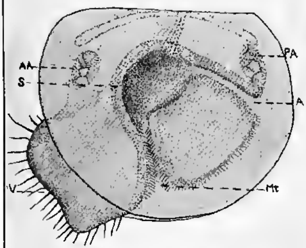

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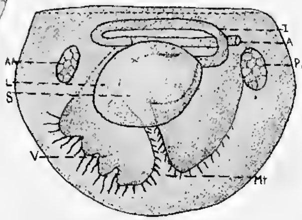

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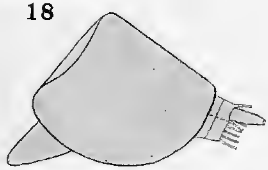

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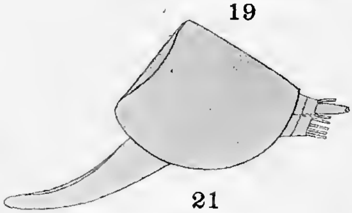

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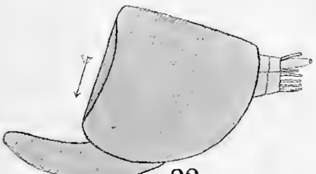

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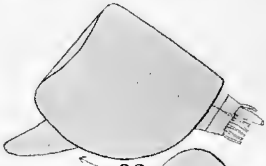

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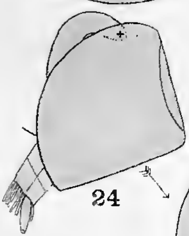

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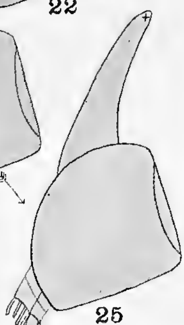

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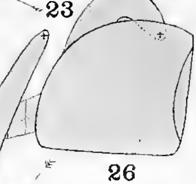

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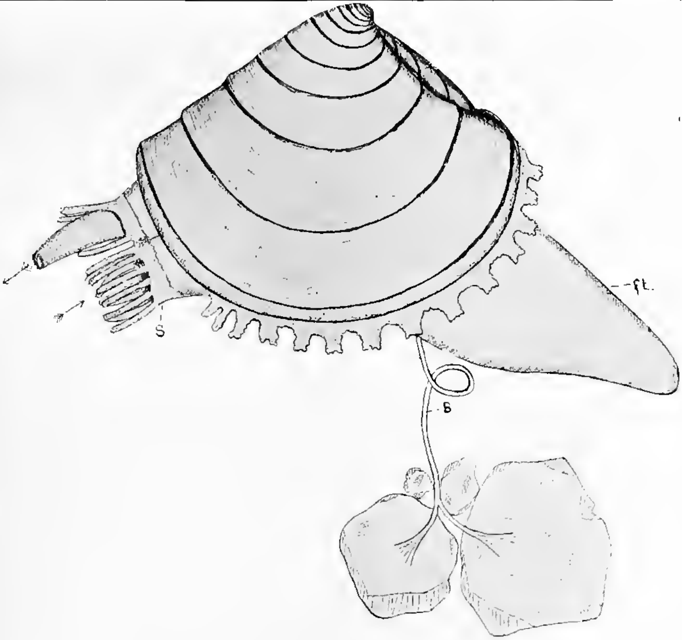
Fig. 28. — Young quahaug, 1 millimeter ($\frac{1}{25}$ inch) in length, attached to sand grains by the byssus (b). The siphon (s) consists of two parts, an incurrent encircled by twelve tentacles, through which the water enters the mantle chamber of the animal, and an excurrent with four tentacles and filmy telescopic tube, through which the water passes out of the mantle cavity. The byssus arises from a gland on the under side of the foot (ft).

Fig. 29. — Young quahaug, 1 millimeter in size, half buried in the sand. The animal is feeding, water passing in and out of the extended siphon, as shown by the arrows.



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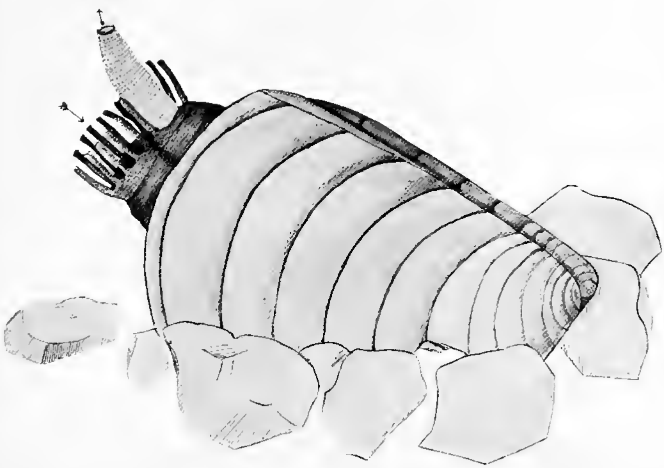

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Fig. 30. — Map showing the distribution of the quahaug in Massachusetts. The black areas indicate ground where quahaugs are found.

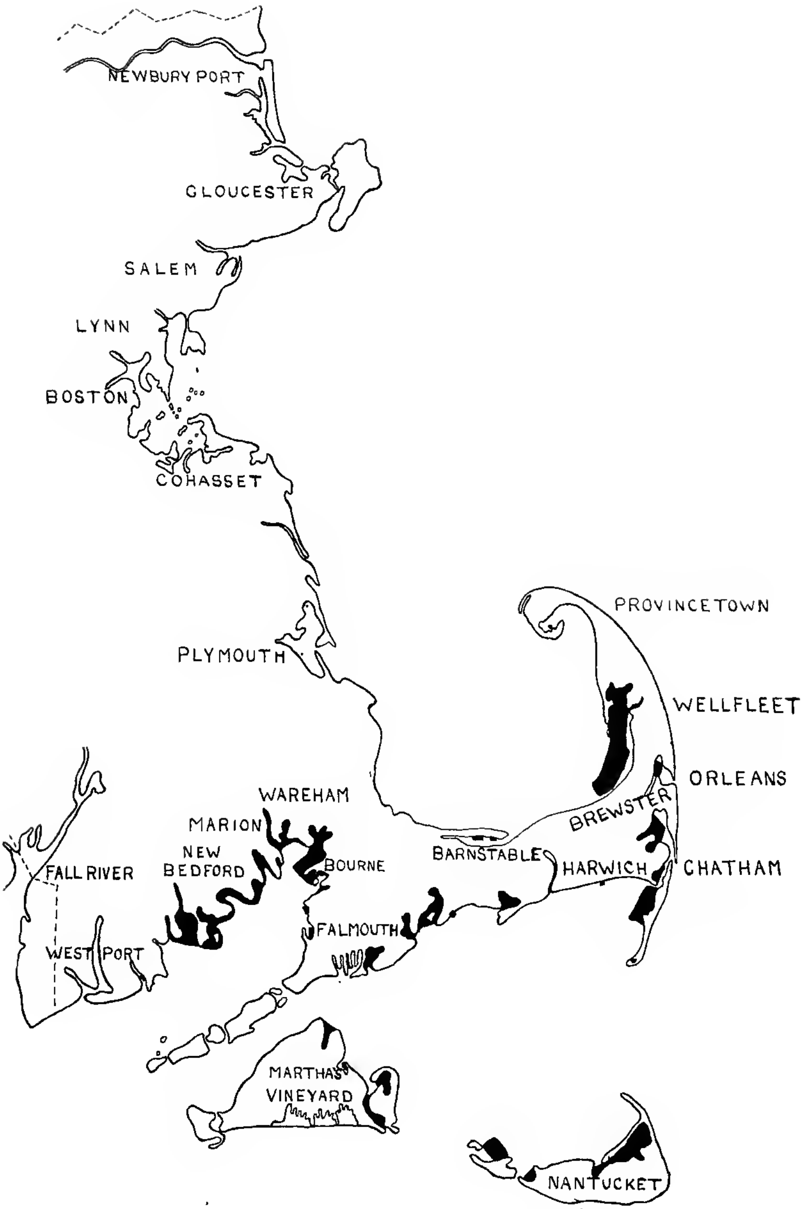
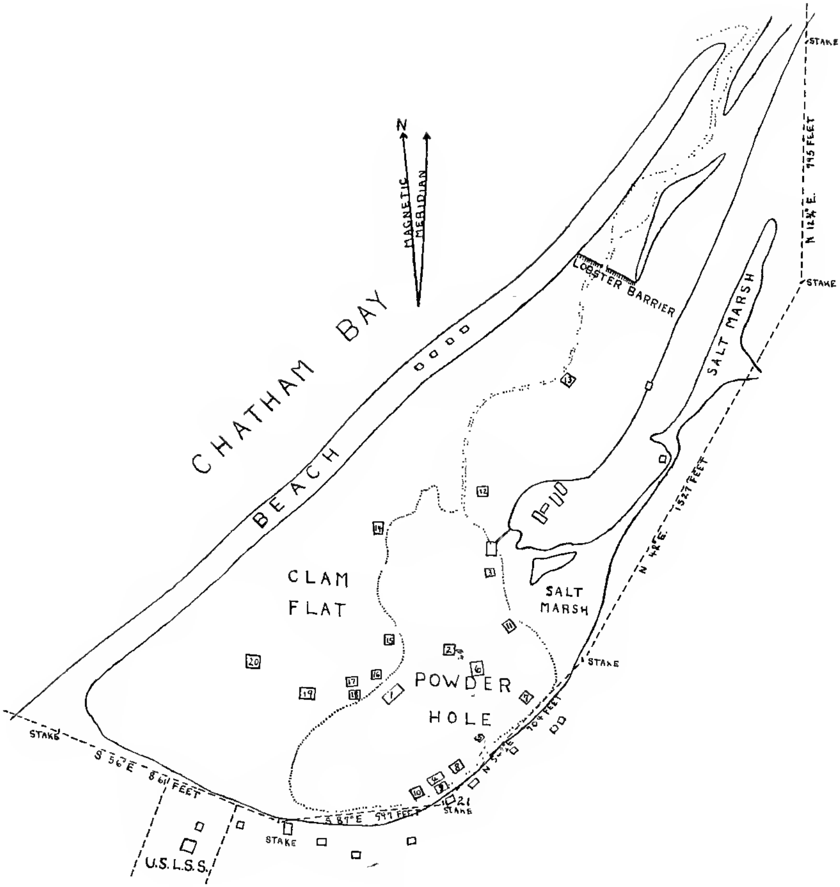

NEWBURY PORT
GLOUCESTER
SALEM
LYNN
BOSTON
COHASSET
PLYMOUTH
PROVINCETOWN
WELLFLEET
ORLEANS
BREWSTER
WAREHAM
MARION
NEW BEDFORD
BOURNE
BARNSTABLE
HARWICH
CHATHAM
FALL RIVER
FALMOUTH
WEST PORT
MARTHA'S VINEYARD
NANTUCKET

Fig. 31. — Plan of the Powder Hole, Monomoy Point, Mass., showing the shellfish experiments and laboratory of the Massachusetts Department of Fisheries and Game. The harbor, represented by the dotted lines, is bounded on the north and west by a clam flat of coarse sand. The channel connecting the Powder Hole with the ocean passes across this flat. The deepest water, 18 feet, is found near the clam flat, while in the eastern and southern parts of the harbor the shallow water is filled with a thick growth of eelgrass. (1) Raft; (2) car in which egg lobsters were confined for hatching purposes; (3) scallop pen; (4) scallop pen; (5) scallop pen; (6) winter rack for suspending scallop baskets and quahaug boxes under water as a protection from the ice; (7) quahaug bed No. 3; (8) quahaug bed No. 5; (9) quahaug bed No. 7; (10) quahaug bed No. 6; (11) quahaug bed No. 8; (12) clam bed No. 19; (13) sea clam bed; (14) clam bed No. 18; (15) clam bed No. 3; (16) clam bed No. 2; (17) clam bed No. 99; (18) clam bed No. 100; (19) clam bed No. 20; (20) clam bed No. 1; (21) laboratory.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MAGNETIC MERIDIAN
CHATHAM BAY
BEACH
LOBSTER BARRIER
SALT MARSH
CLAM FLAT
POWDER HOLE
SALT MARSH
STAKE
N 12¾° E. 995 FEET
STAKE
N 42° E. 1527 FEET
STAKE
704 FEET
STAKE
S 56° E 861 FEET
S 87° E 997 FEET
STAKE
STAKE
U.S.L.S.S.

Fig. 32. — Map of Wellfleet Bay showing the loeation between the tide lines of quahaug growth experiments 101 to 185. Many aeres of flats are exposed, owing to the large rise and fall of the tide, whieh is about $10\frac{3}{4}$ feet. The average inerease in volume for 84 beds in one year was 185 per cent., or over $2\frac{3}{4}$ bushels for every bushel planted.

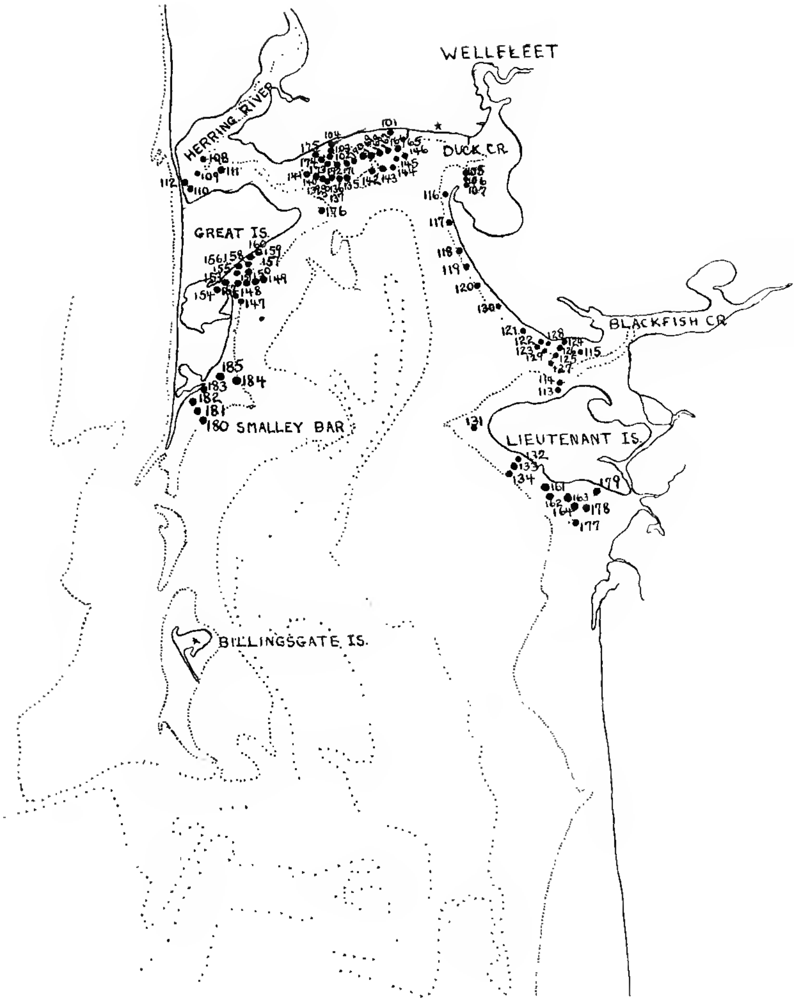
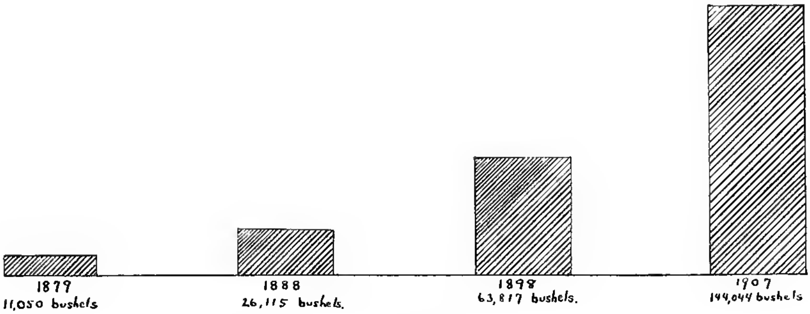

WELLFLEET
HERRING RIVER
DUCK CR.
GREAT IS.
BLACKFISH CR.
SMALLEY BAR
LIEUTENANT IS.
BILLINGSGATE IS.

Fig. 33. — The increase in quahaug production for Massachusetts from 1879 to 1907 is represented by a series of columns, corresponding to the annual yield for 1879, 1888, 1898 and 1907. The figures for the first three years are taken from the reports of the United States Bureau of Fisheries.

Fig. 34. — The increase in value for the annual production of these years is similarly represented.

Fig. 35. — The rise in price per bushel for these years illustrates that the increased demand and high cost of living have made quahauging a remunerative business, in spite of the fact that the daily yield of the individual quahauger has become less.



Production

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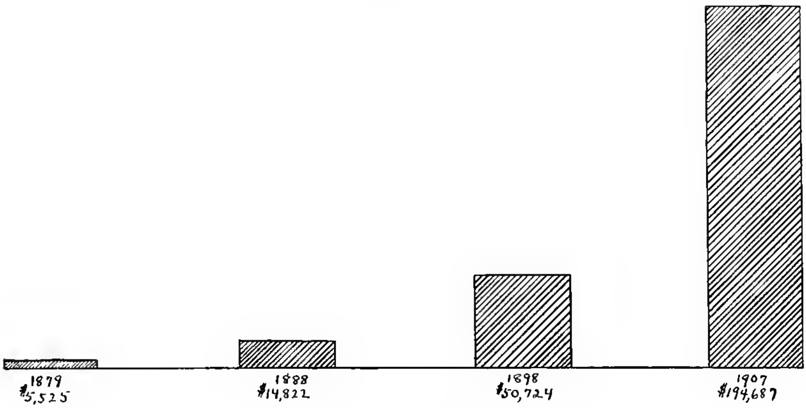

Value of Production

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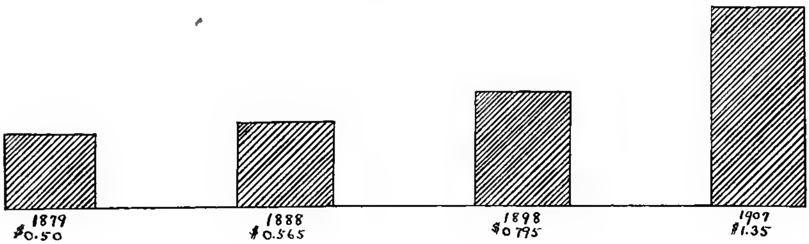


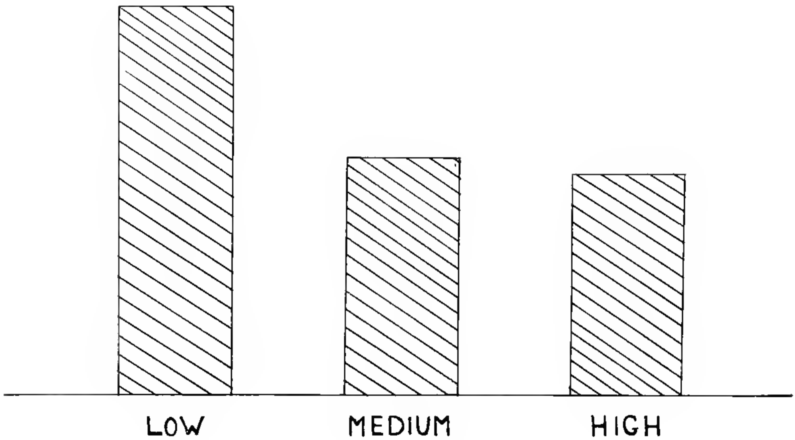
Rise in Price per Bushel

35

Fig. 36. — Growth between the Tide Lines. — Eighty beds, planted between the tide lines at Wellfleet, were classified as *low*, *medium* and *high*, according to the length of time exposed. The *low* beds, 32 in number, having a better circulation and longer feeding period, gave a growth of 12.5 millimeters (.49 inch) in one year; the 27 *medium* beds gave 7.82 millimeters (.31 inch); and the 21 *high* beds showed a gain of 7.17 millimeters (.28 inch). Considering the growth of the *low* beds as 100 per cent., the *medium* would show 61.53 per cent., and the *high* 57.39 per cent.

Fig. 37. — Age and Growth. — With age the rate of growth both in actual increase and gain in volume becomes less. The three columns represent the comparative annual increase in length of 21.2 millimeters (.83 inch), 10.5 millimeters (.41 inch) and 5 millimeters (.20 inch) for quahaugs one and one-half, three and one-half, and five and one-half years old, planted in boxes suspended from a raft at Monomoy Point.

Fig. 38. — Current and Growth. — The three columns represent the comparative increase in length during 1909 for small quahaugs planted in three sections of the Powder Hole. The highest column shows the average growth 27.23 millimeters (1.07 inches), in the raft boxes, where the circulation of water was good; the second column shows a growth of 19.44 millimeters (.77 inch) in boxes near the south shore of the Powder Hole, in front of the laboratory, where there is a slight current; the third column shows a growth of 14.94 millimeters (.59 inch) in boxes near the southeast shore, where there was practically no circulation, owing to the thick eelgrass.



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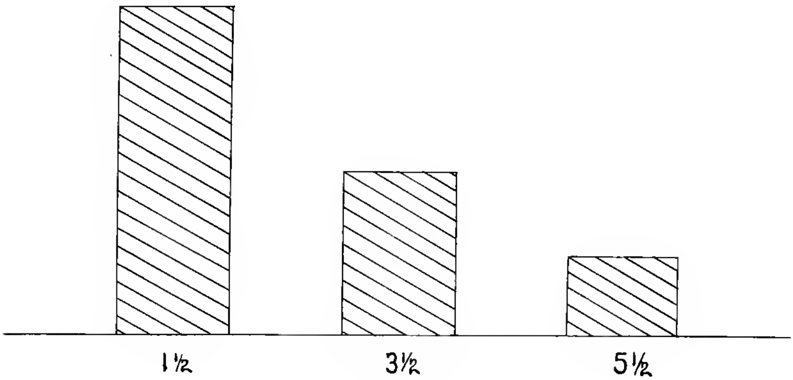

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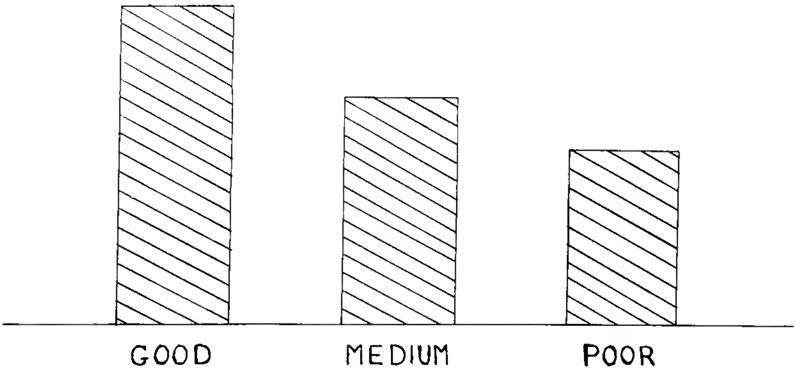

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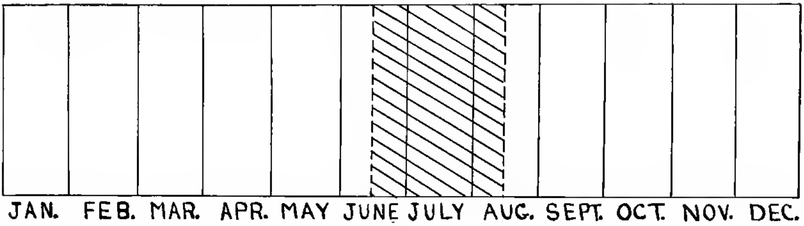
Fig. 39. — The Spawning Months. — The spawning season lasts from the middle of June to the middle of August. This period is represented by the shaded portion.

Fig. 40. — The Growing Months. — The quahaug increases in size of shell only during the summer months, growth ceasing during the cold weather. The shaded portion represents the period of growth.

Fig. 41. — The Relative Value of the Growing Months. — The quahaug does not increase with equal rapidity during the seven months of growth. The relative value of these months is represented in terms of the increase during each month for a standard quahaug. Considering the total annual growth as 100 per cent., the following are the values for the individual months: May, 3.78 per cent.; June, 10.81 per cent.; July, 19.02 per cent.; August, 25.56 per cent.; September, 26.24 per cent.; October, 12.85 per cent.; November, 1.74 per cent.

Fig. 42. — The Food Value. — The relative proportion, by weight, of the various parts of an average quahaug of 70 millimeters (2.75 inches) is represented by a series of columns. (1) Total weight, 100 per cent.; (2) shell, 62.47 per cent. (3) meat, 13.57 per cent.; (4) fluid, 23.96 per cent.



SPAWNING MONTHS

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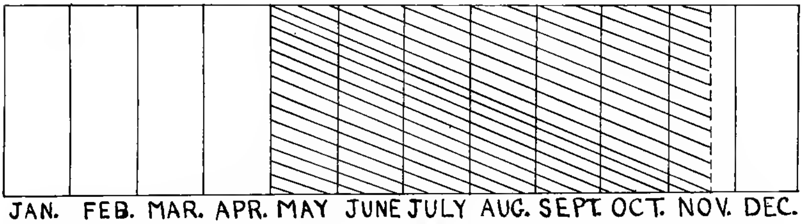

GROWING MONTHS

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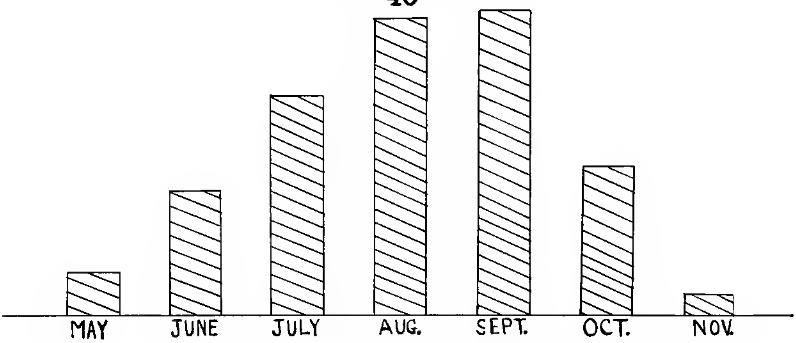

RELATIVE VALUE

OF GROWING MONTHS

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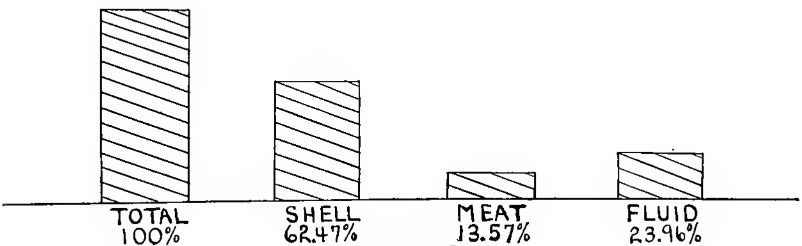


FOOD VALUE

42

Fig. 43. — Growth of a standard 25 millimeters (1 inch) quahaug for fourteen months, showing the cessation of growth during cold weather: —

	Millimeters.		Millimeters.
May 1,	25.00	January 1,	47.00
June 1,	26.00	February 1,	47.00
July 1,	28.80	March 1,	47.00
August 1,	33.50	April 1,	47.00
September 1,	39.20	May 1,	47.00
October 1,	44.40	June 1,	47.65
November 1,	46.70	July 1,	49.47
December 1,	47.00		

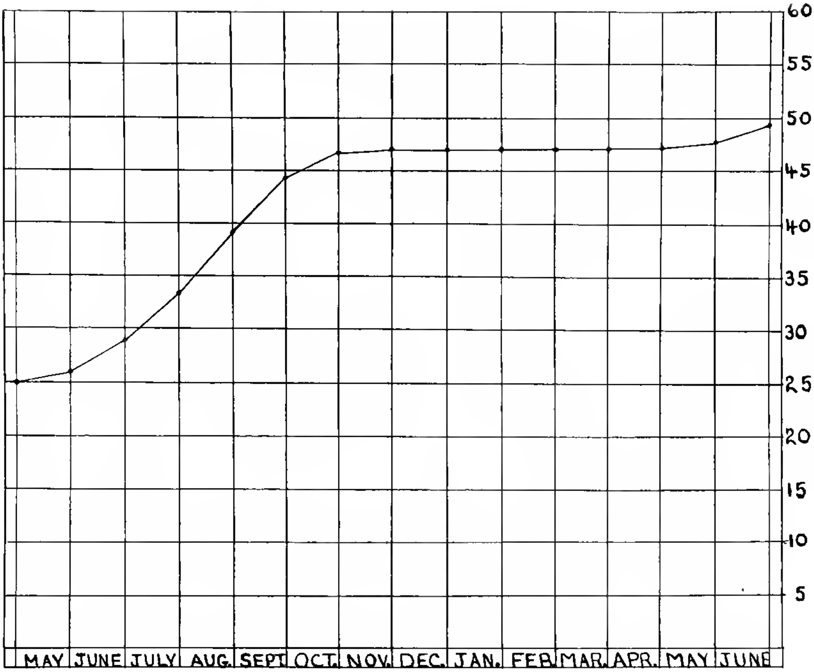
Fig. 44. — Growth for Four Years. — The growth of the average quahaug from two series of experimental beds is here given for a period of four years, starting with a quahaug of 5 millimeters (⅕ inch) at the age of one-half year. Note the difference between the rapid growth at Monomoy Point and the slower Wellfleet beds, also the decrease in the rate of growth as the quahaug increases in size.

Growth in the Raft Boxes at Monomoy Point (Millimeters).

Month.	First Year.	Second Year.	Third Year.	Fourth Year.
January 1,	5.00	28.73	49.11	62.66
February 1,	5.00	28.73	49 11	62.66
March 1,	5.00	28.73	49.11	62.66
April 1,	5.00	28.73	49.11	62.66
May 1,	5.00	28.73	49.11	62.66
June 1,	5.73	29.50	49.62	63.03
July 1,	7.93	31.70	51.08	64.10
August 1,	12.42	35.58	53.66	65.98
September 1,	19.17	40.79	57.12	68.51
October 1,	25.59	46.14	60.68	71.11
November 1,	28.38	48.76	62.42	72.38
December 1,	28.73	49.11	62.66	72.55
Annual gain,	23.73	20.38	13.55	9.89

Growth between the Tide Lines in Wellfleet Harbor (Millimeters).

Month.	First Year.	Second Year.	Third Year.	Fourth Year.
January 1,	5.00	16.21	27.48	36.69
February 1,	5.00	16.21	27.48	36.69
March 1,	5.00	16.21	27.48	36.69
April 1,	5.00	16.21	27.48	36.69
May 1,	5.00	16.21	27.48	36.69
June 1,	5.51	16.72	27 90	37.04
July 1,	6.94	18.16	29.07	38.01
August 1,	9.33	20.57	31.04	39.64
September 1,	12.23	23.49	33.42	41 61
October 1,	14.89	26.15	35.60	43.41
November 1,	16.06	27.33	36.56	44.21
December 1,	16 21	27.48	36.69	44.31
Annual gain,	11.21	11.27	9.21	7.62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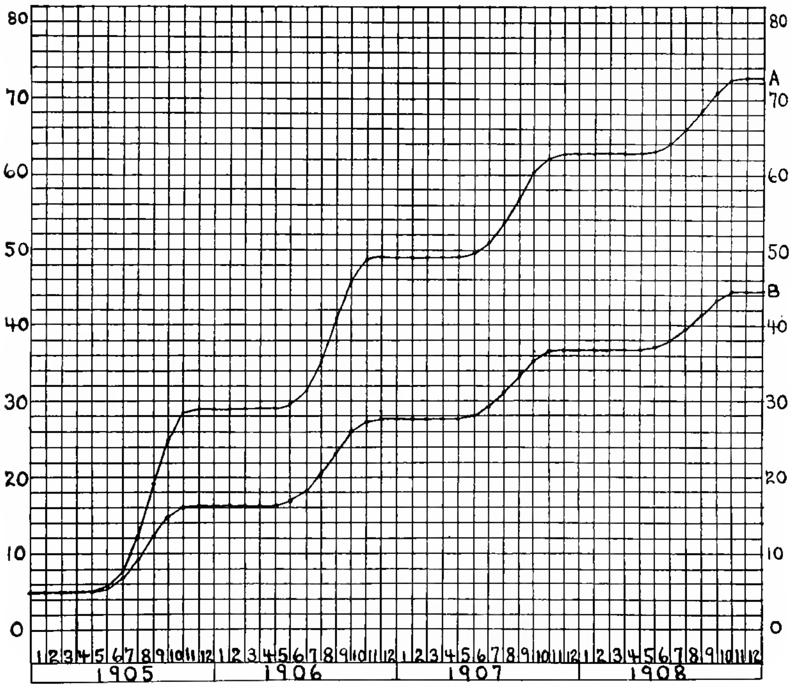
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1906
1907
1908

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Fig. 45. — The growth of a quahaug in the raft boxes, Monomoy Point, from one and one-half to five and one-half years old, is shown with the corresponding increase in volume. Starting with 1 bushel of one and one-half-year-old quahaugs there would result at the age of five and one-half years approximately 19 bushels. The figures on the left give the size of the quahaug (reduced one-half); those on the right represent the volume in bushels corresponding to the various years.

Age (Years).	Size.		Volume (Bushels).
	Millimeters.	Inches.	
One and one-half,	28.73	1.13	1.00
Two and one-half,	49.11	1.93	4.44
Three and one-half,	62.66	2.47	9.10
Four and one-half,	72.55	2.86	14.04
Five and one-half,	79.90	3.18	18.96

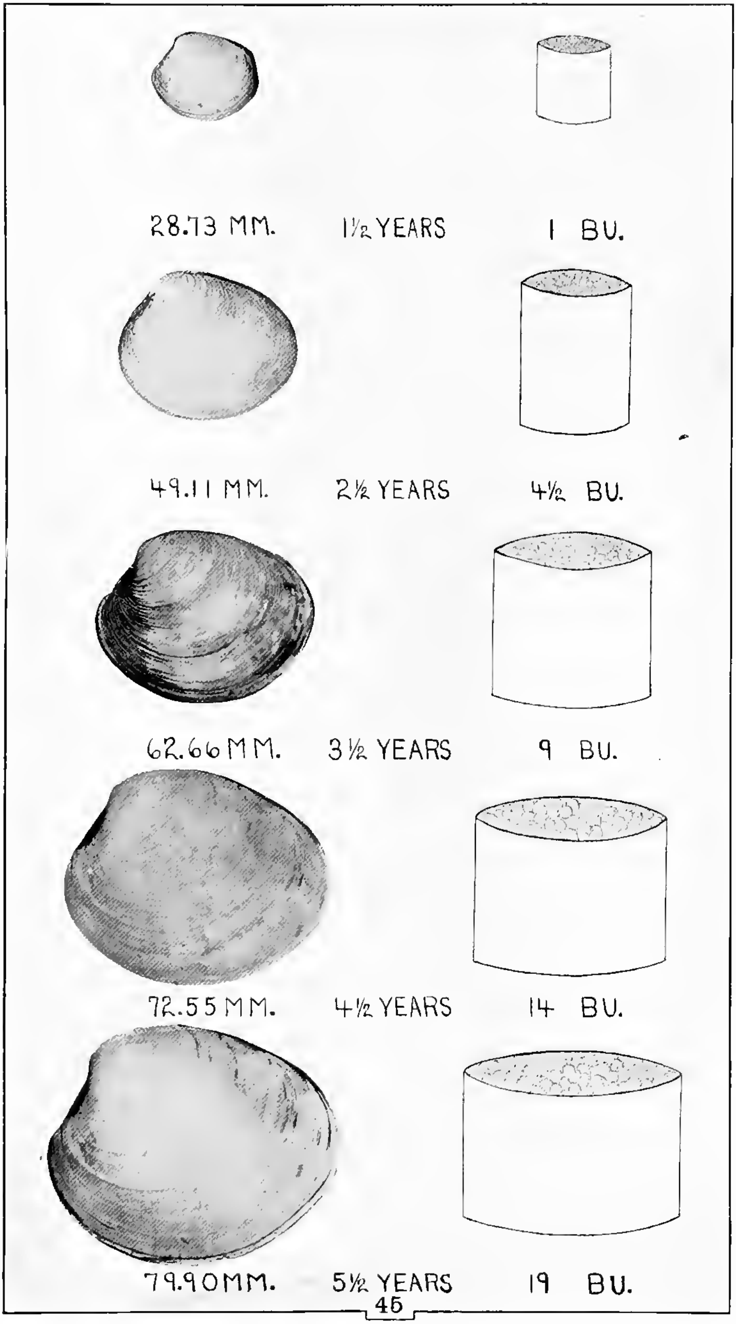
28.73 MM.
1½ YEARS
1 BU.
49.11 MM.
2½ YEARS
4½ BU.
62.66 MM.
3½ YEARS
9 BU.
72.55 MM.
4½ YEARS
14 BU.
79.90 MM.
5½ YEARS
19 BU.

Fig. 46. — Diagram of the method used in experimental hatching of quahaug eggs and rearing of the young larvæ at the Wellfleet laboratory. It represents a cross-section of the laboratory, showing a small $1\frac{1}{2}$ horse power gasolene engine (B), connected by a belt with a pump (C), by which salt water is forced from below into a tank (A) situated near the roof. The laboratory is located on a wharf over the water, which enables salt water to be obtained directly from beneath the floor. The inlet of the pump is guarded by a strainer (H), which prevents seaweed entering the pipe. From the tank the salt water is conducted through the laboratory by a large pipe set with small petcocks. From these petcocks pieces of rubber tubing (F) lead to the hatching tubs (E), which consist of half barrels fitted with sand filters (D). The tubs are placed over a sink (G) which carries off the filtered water. By this arrangement a continuous flow of water is established through the hatching tanks.

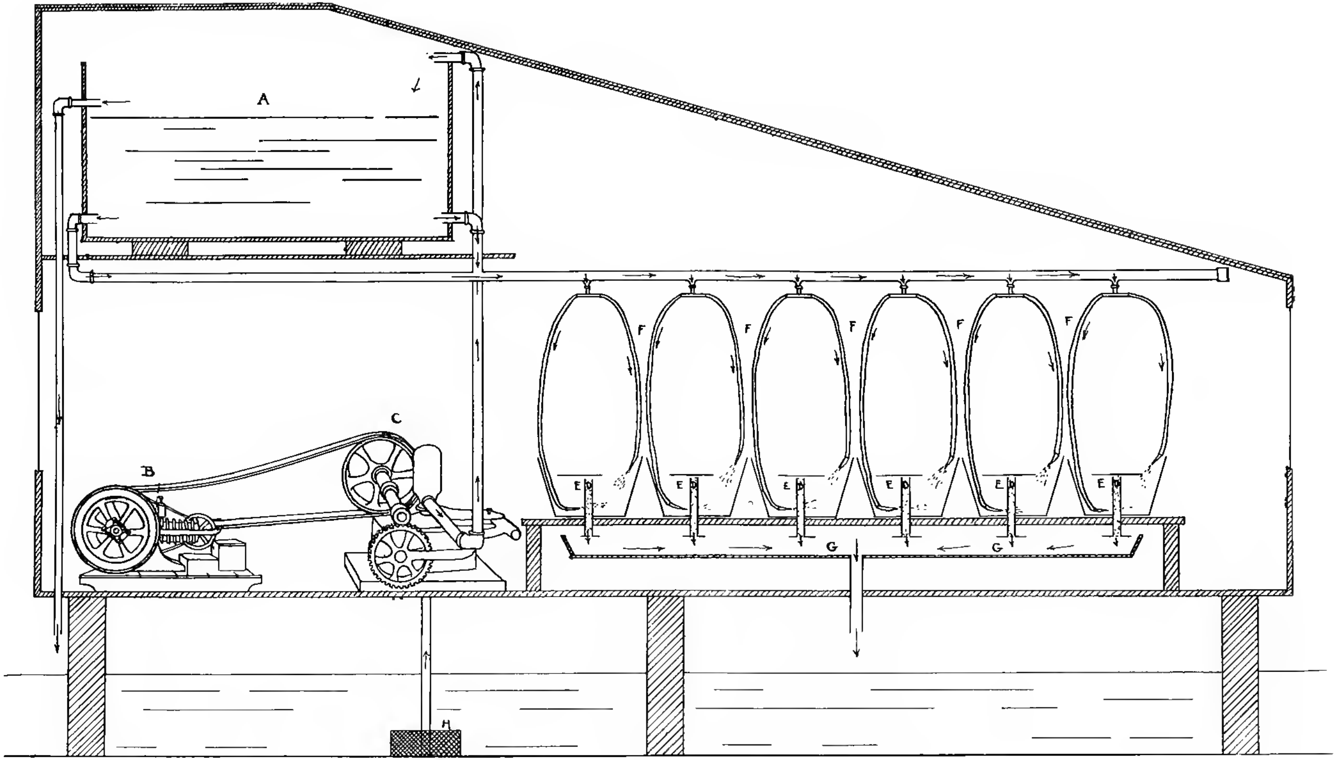

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Fig. 47. — Photograph taken from a model in the Museum of Natural History in New York. The different portions of the anatomy are indicated by the labels, The symbol A. A. and P. A. refer to the anterior and posterior adductor muscles. which hold the two valves of the shell together. The posterior part of the animal is represented by the siphon, which consists of two parts, an incurrent and an excurrent, through which the water enters and leaves the quahaug in the directions indicated by the arrows. In the mantle chamber the food is filtered from the water by the gills, which are here shown cut off near their base.

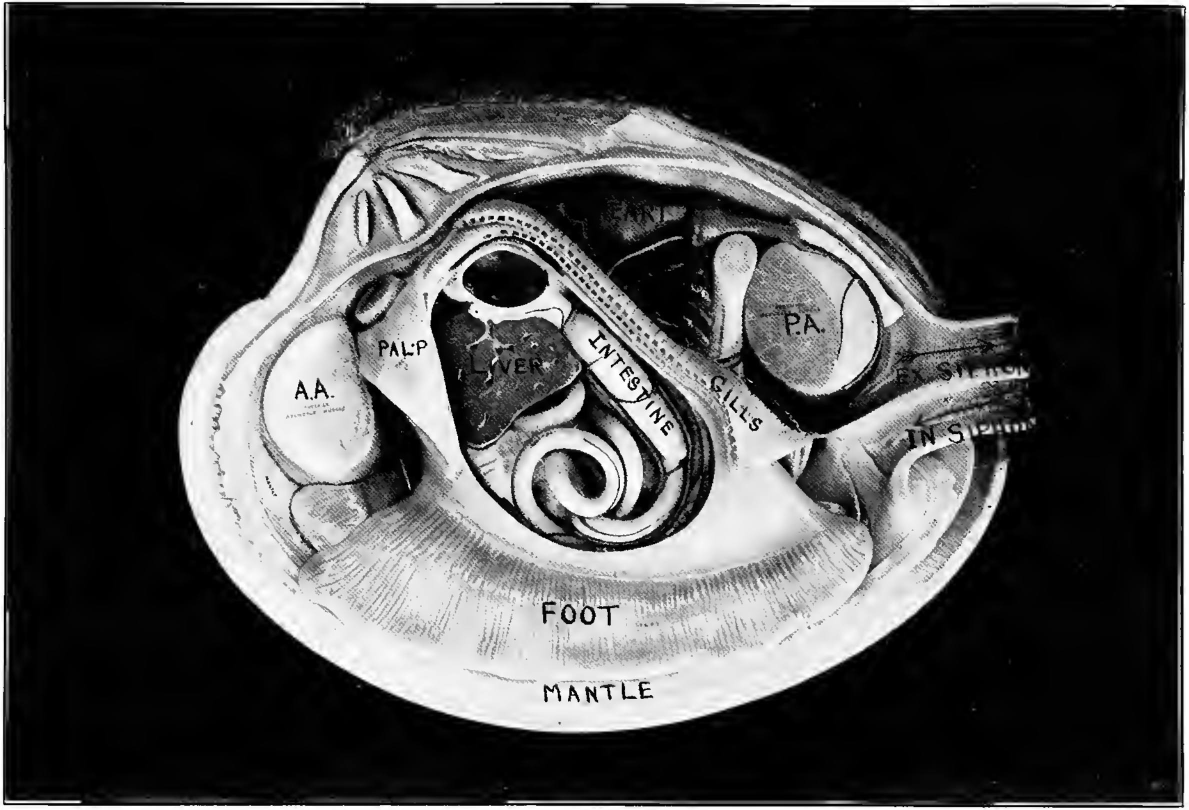
A.A.
PAL.P
LIVER
INTESTINE
GILLS
P.A.
FOOT
MANTLE

Fig. 48. — The exterior of the laboratory at Wellfleet, showing the hatching tubs. This building, formerly an oyster house situated on the Chequesset Inn wharf, was provided in 1908 for the use of the department by Mr. L. D. Baker of Wellfleet. One large room, 20 by 30 feet, is used for the laboratory, while two small rooms adjoining are utilized for sleeping quarters. The situation over the water affords satisfactory facilities for experimental work on sea forms.

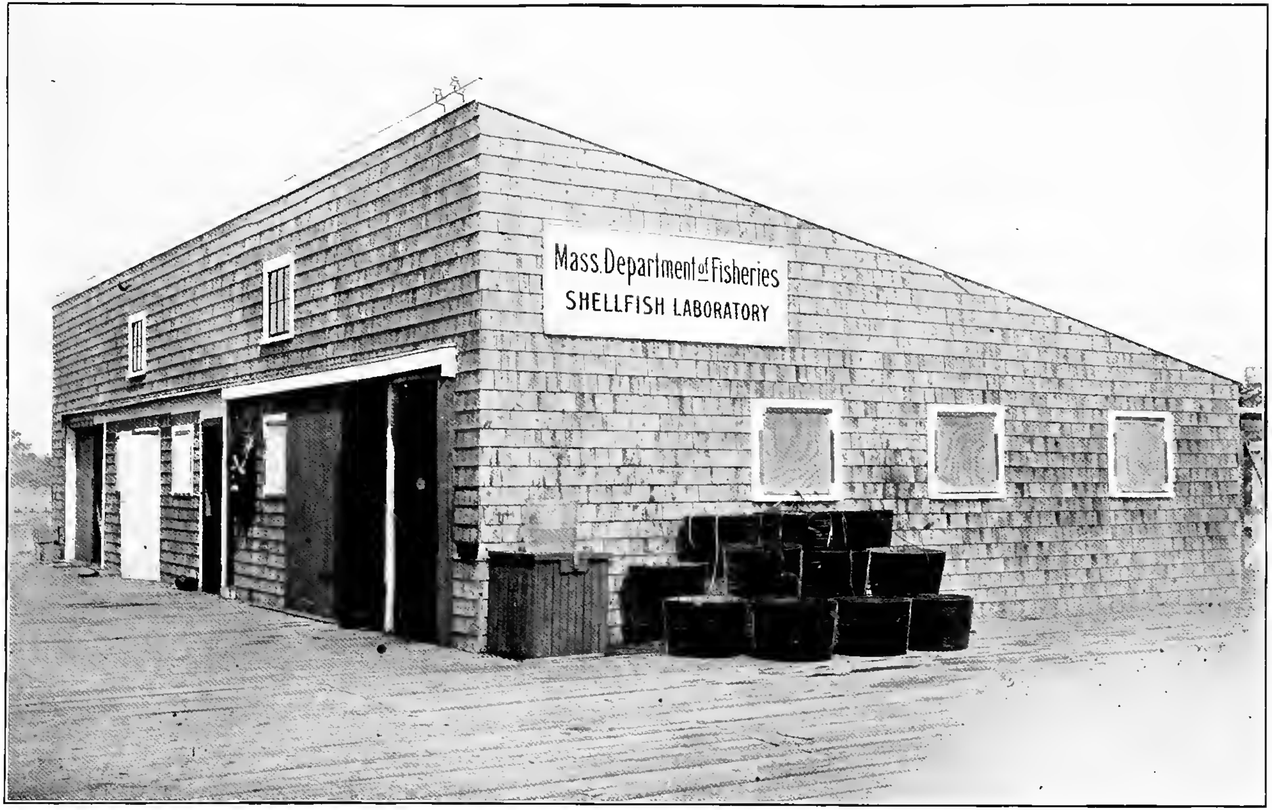
Mass. Department of Fisheries
SHELLFISH LABORATORY

Fig. 49. — The quahaug farm of Z. A. Howes at Wellfleet. Several hundred bushels of seed quahaugs are planted between the tide lines. The boundaries of the grant are marked with stakes, made of slender saplings topped with brush. The man in the foreground is examining the growth of the quahaugs.

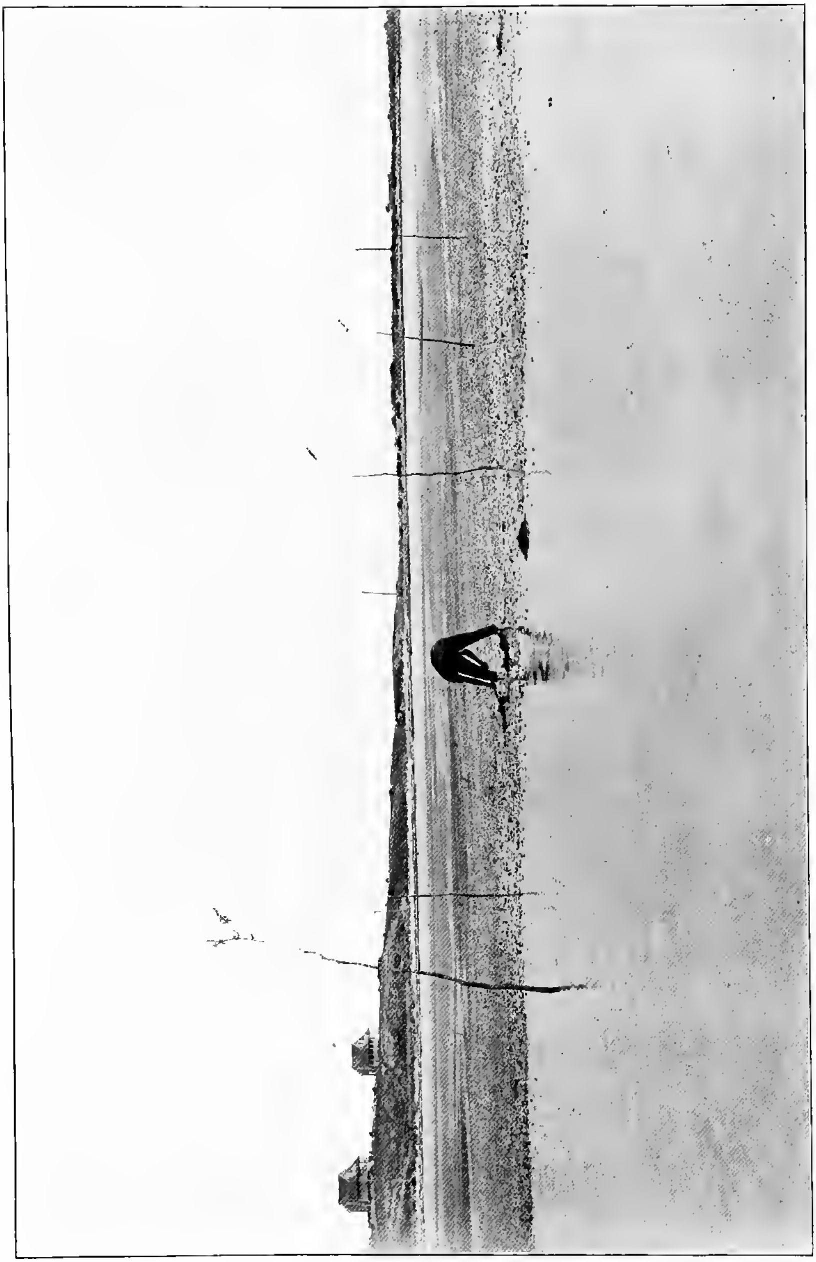

Fig. 50. — Small grants for the bedding of the catch at Wellfleet. Under the Acts of 1904 the inhabitants of Eastham, Orleans and Wellfleet have the privilege of staking off not over 75 feet square of flat for bedding the catch, when the prices are low. During dull seasons many bushels of "blunts" are planted until the price becomes satisfactory. This may be termed the first step toward quahaug culture. Note the quahaugs in the center, which are still uncovered.

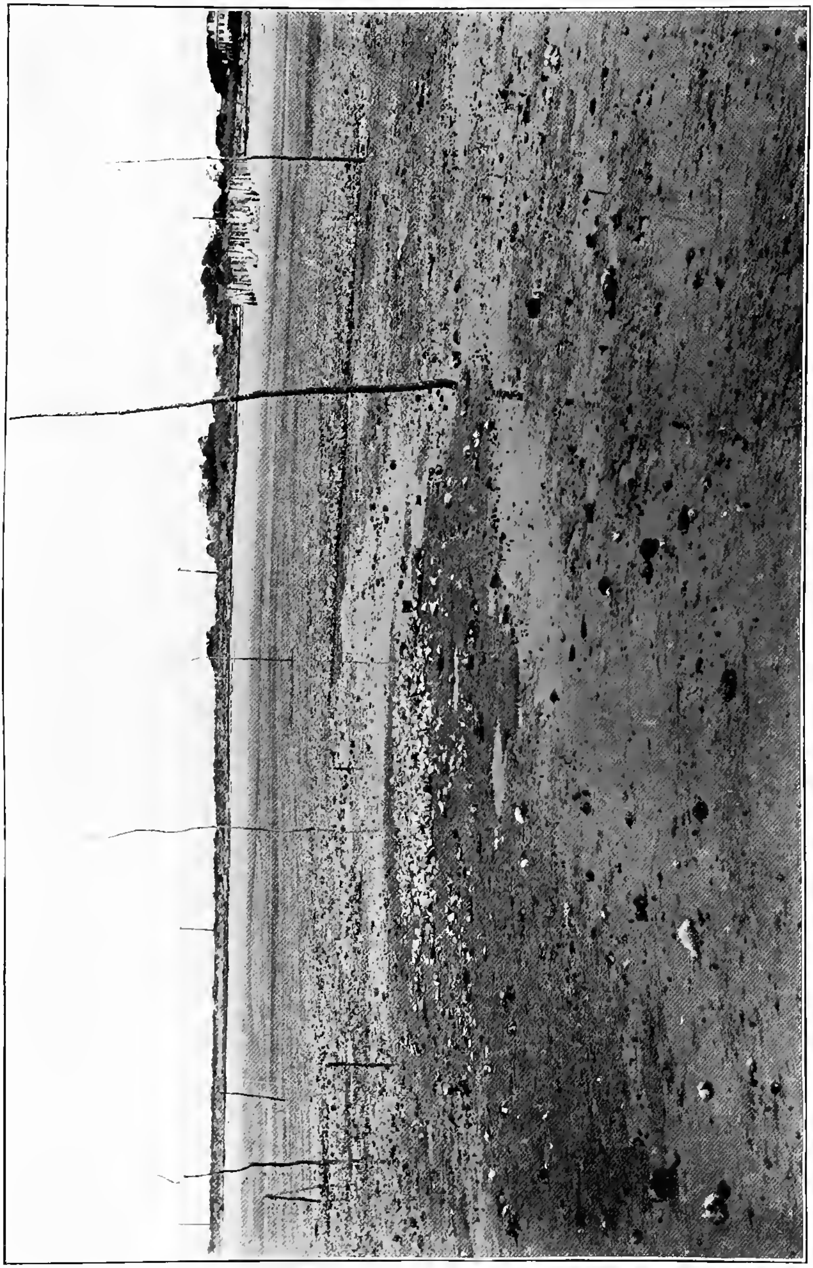

Fig. 51. — One of the boxes suspended from the raft at Monomoy Point when taken up at the end of the summer. The quahaugs which have been growing in the box are shown in front. On careful examination the notches in the shell, marking growth for three years, can be seen. The box and rope are covered with barnacles and silver shells (*Anomia*), while the wood has been perforated by a boring mollusk, the shipworm (*Toredo*). This illustrates an easy method of obtaining the rate of growth of the quahaug.

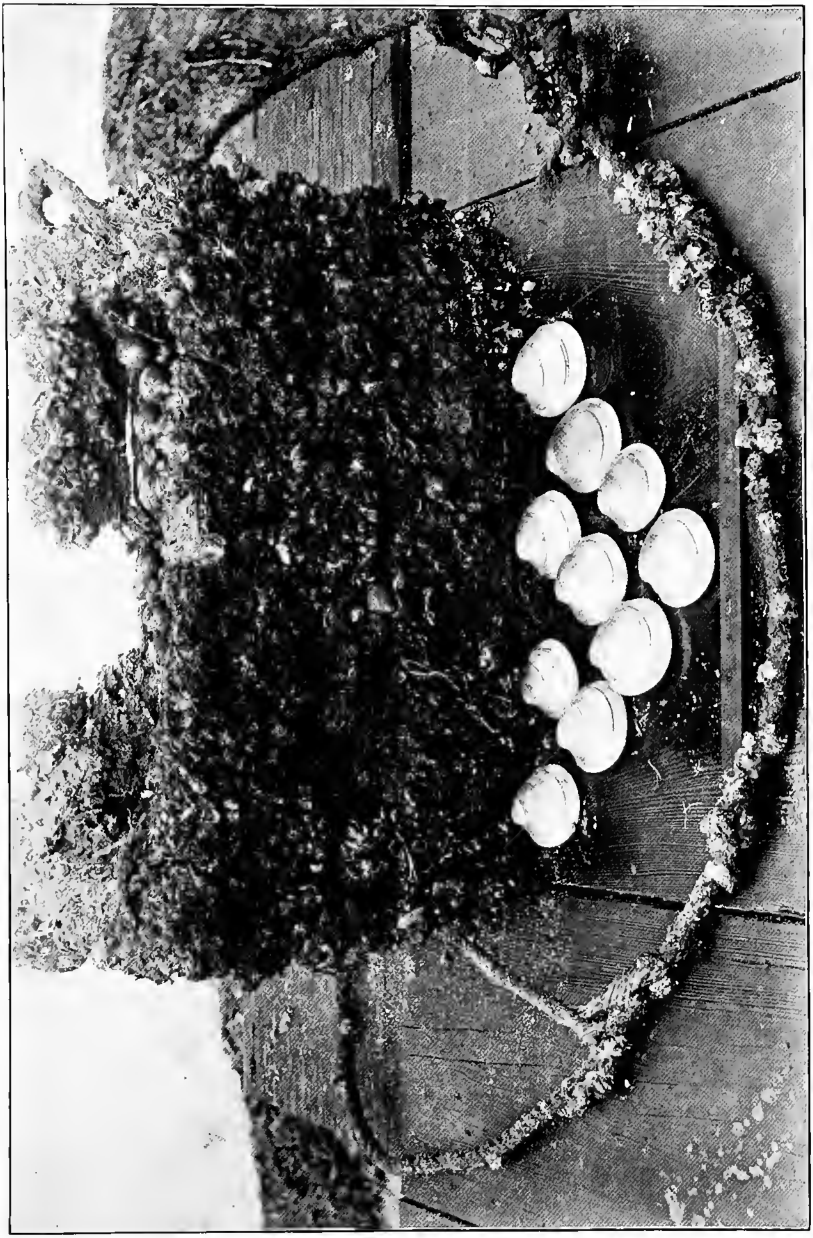

Fig. 52. — These two sizes illustrate the stimulating effect on growth of current, which acts as a food carrier. In each bed quahaugs of the same size were planted and allowed to remain for three years. The larger quahaugs were planted in a box on the raft, where the circulation of water was good; the smaller in the south-eastern corner of the Powder Hole, not 75 yards from the raft, in shallow water among thick eelgrass, which shut off all circulation.

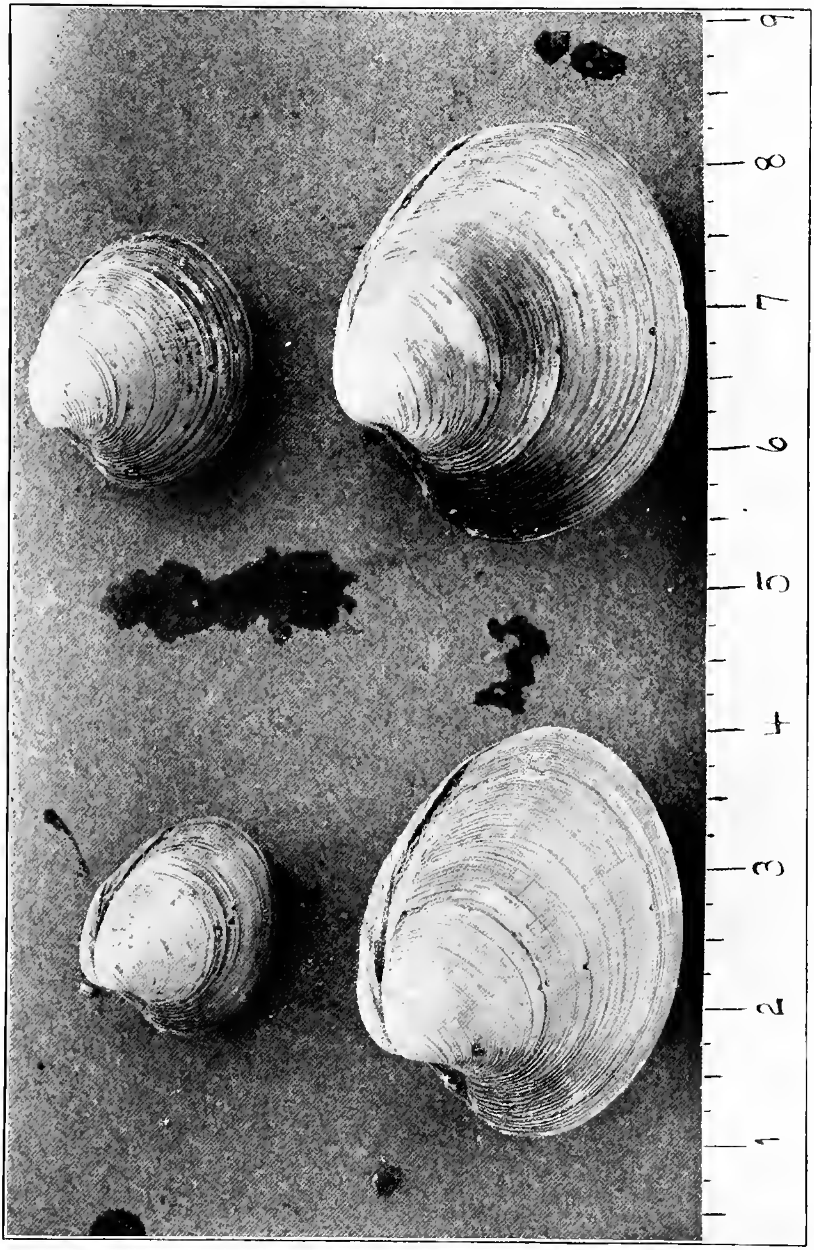
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Fig. 53. — Quahaugs from an experimental bed at Monomoy Point, showing two years' growth. The two notches or file marks on the shells indicate the growth per year. The photograph is two-thirds life size. These quahaugs show rapid growth, having gained nearly 1 inch in length per year.

Fig. 54. — The principal enemy of the adult quahaug is the common winkle or cockle (*Lunatia duplicata* or *heros*), pictured at the right and left in the illustration. In the corners are quahaug shells, through which a clean countersunk hole has been bored by this mollusk at the umbo. In the center is a starfish, the great pest of the oyster beds, and on rare occasions an enemy of the quahaugs.

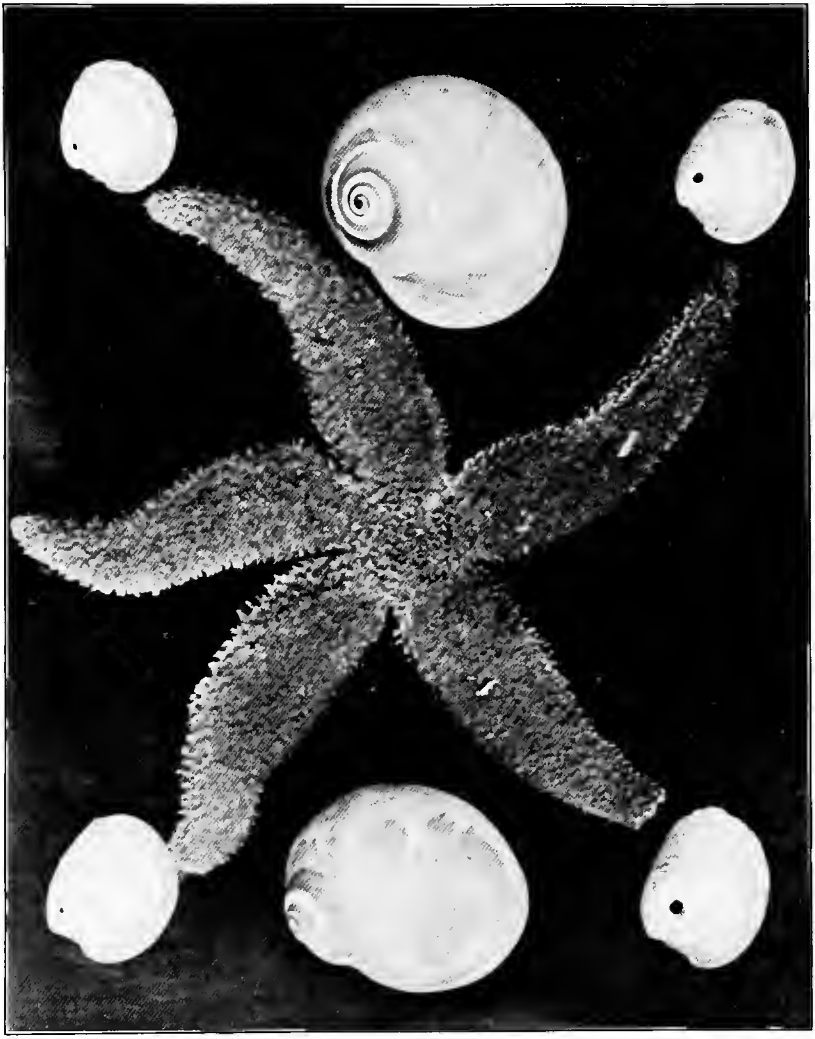


Fig. 55. — Scene along the river front at Fairhaven, showing a quahaug shanty and several skiffs, which are used in raking the small seed quahaugs from the Acushnet River. Owing to the pollution within the restricted area, quahaugs can only be taken from this river for transplanting purposes. Since writing this report an act was passed in 1911 whereby the city of New Bedford and the town of Fairhaven by a common board govern the taking of quahaugs from this section by licenses and by restrictions as to selling and transplanting.

Fig. 56. — The quahaug house of the firm of A. D. Davis & Co. at Wellfleet in 1907, one of the receiving agencies for the Wellfleet fishermen. A typical quahauging boat of Wellfleet is shown, waiting to unload its cargo of quahaugs. The long handles of the rakes can be seen on the deck of the boat.

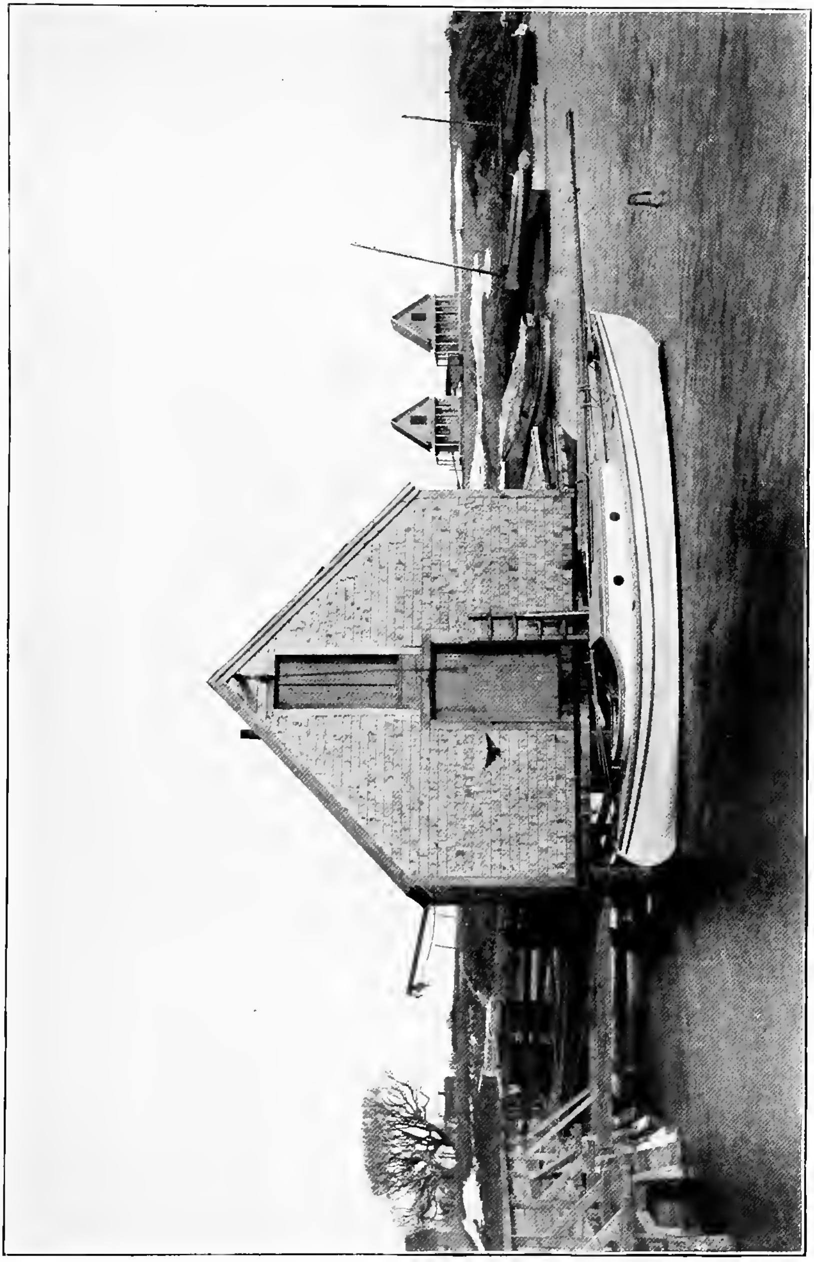


Fig. 57. — The Wellfleet quahauging fleet at their moorings in Duck Creek. Practically all these boats are equipped with gasolene engines, a common type being power cat boats without masts.

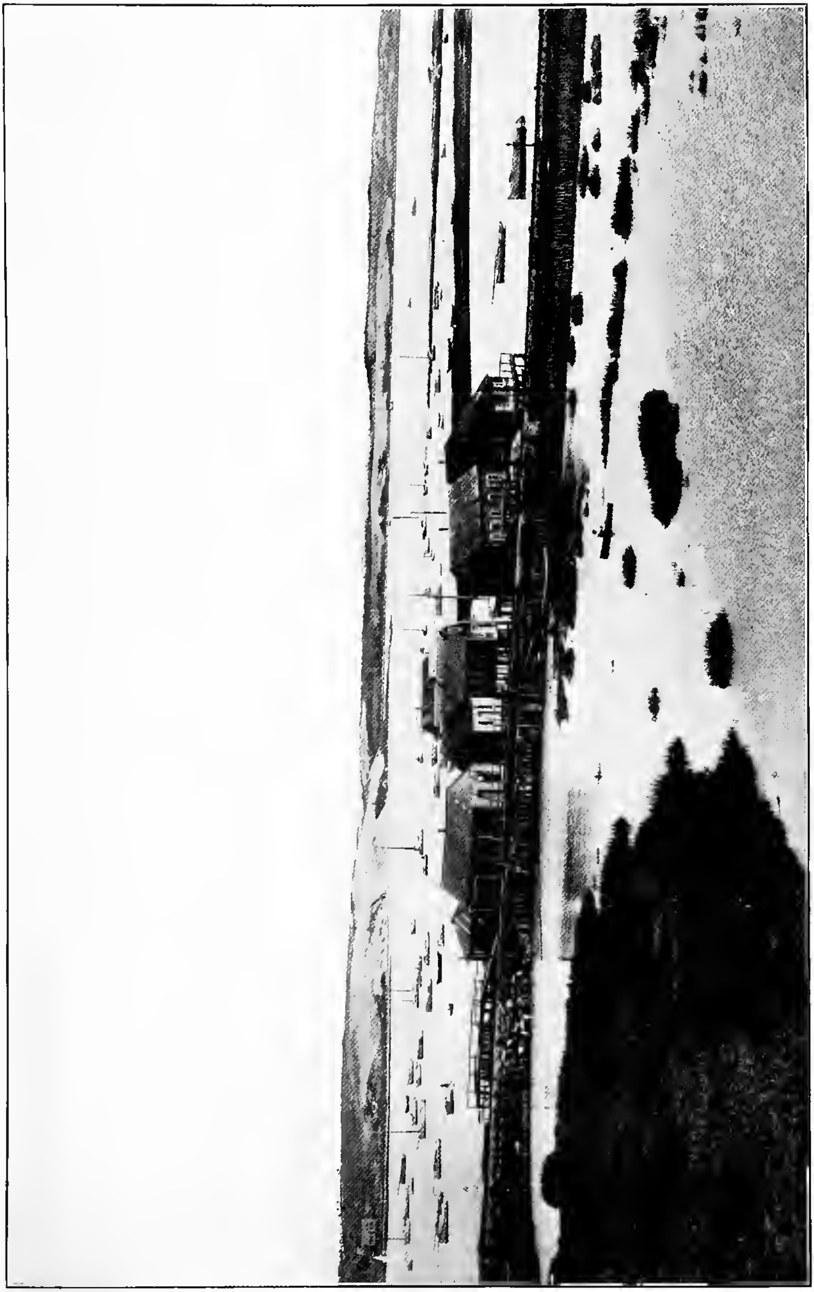


Fig. 58. — Basket rake covered with fine meshed wire netting, used at New Bedford and Fairhaven in the capture of the small seed quahaugs in the Acushnet River.

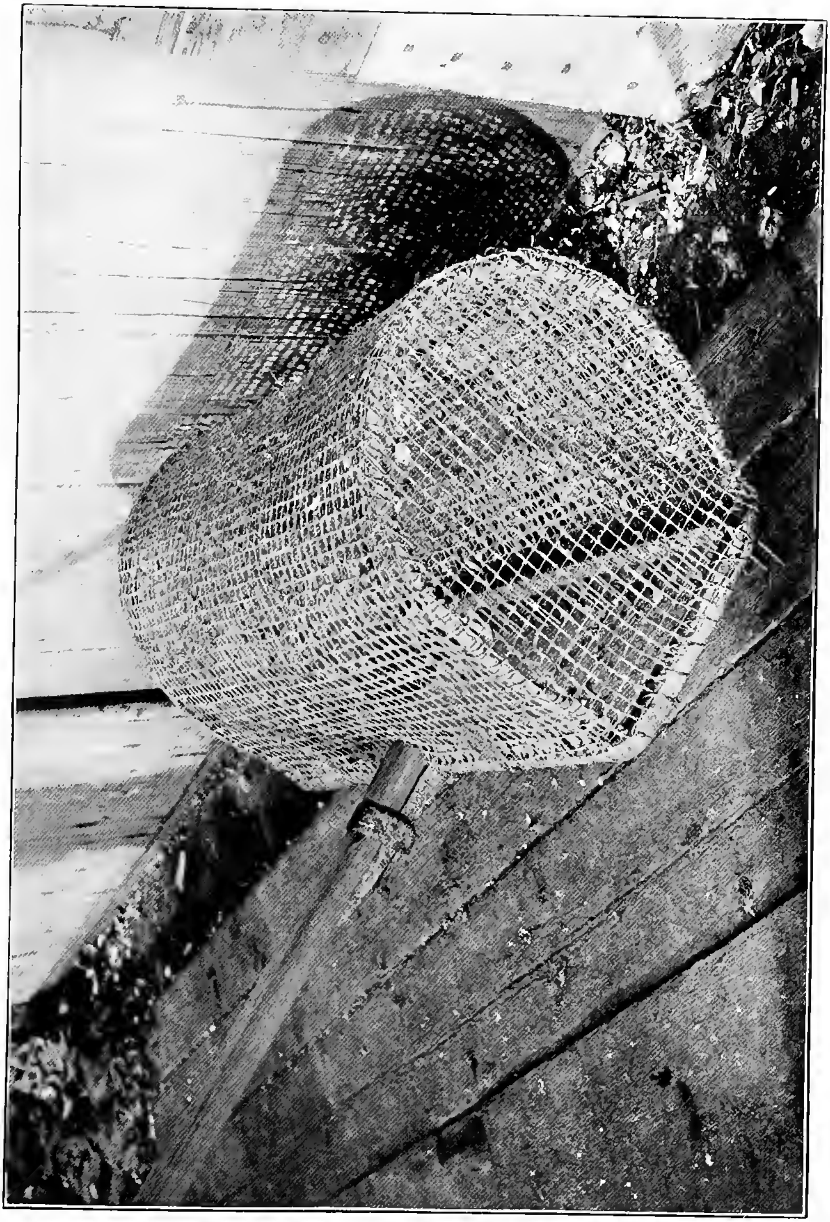


Fig. 59. — The type of basket rake used for deep water quahauging on Cape Cod. It consists of an iron framework, forming a curved bowl, the under edge of which is set with thin steel teeth varying in length from 2 to 4 inches, though usually 2½ inch teeth are preferred. Over the bowl of this rake, which is strengthened by side and cross pieces of iron, is fitted a twine net, which, like the net of a scallop dredge, drags behind the framework. An average rake has from 19 to 21 teeth and weighs from 15 to 20 pounds.

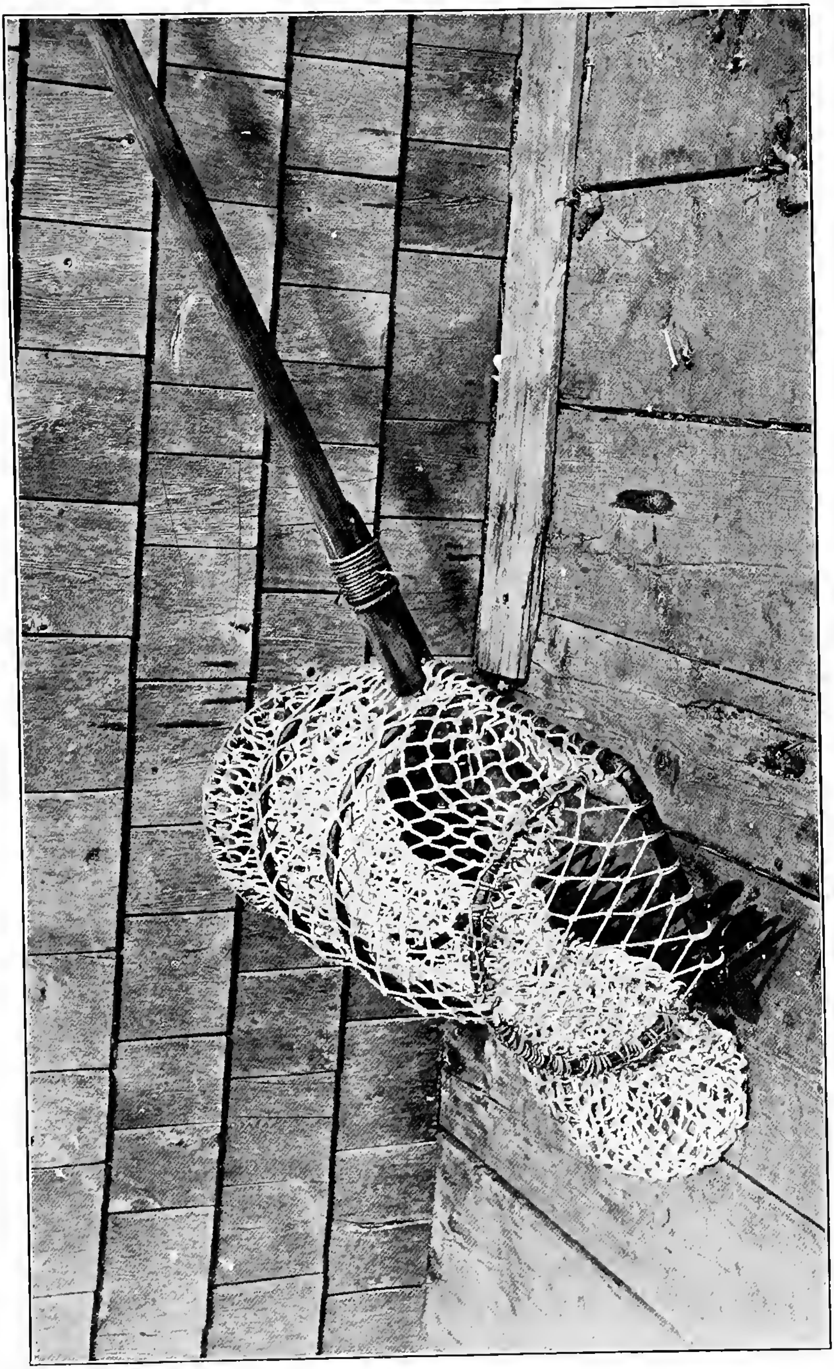


Fig. 60. — The Claw Quahaug Rake. — This rake varies greatly in size and length. Its use is chiefly confined to Nantucket. The general style has a handle 6 feet long, while the iron part, in the form of a claw or talon, with prongs 1 inch apart, is 10 inches wide. A heavier rake, as here shown, is sometimes used in the deeper water.

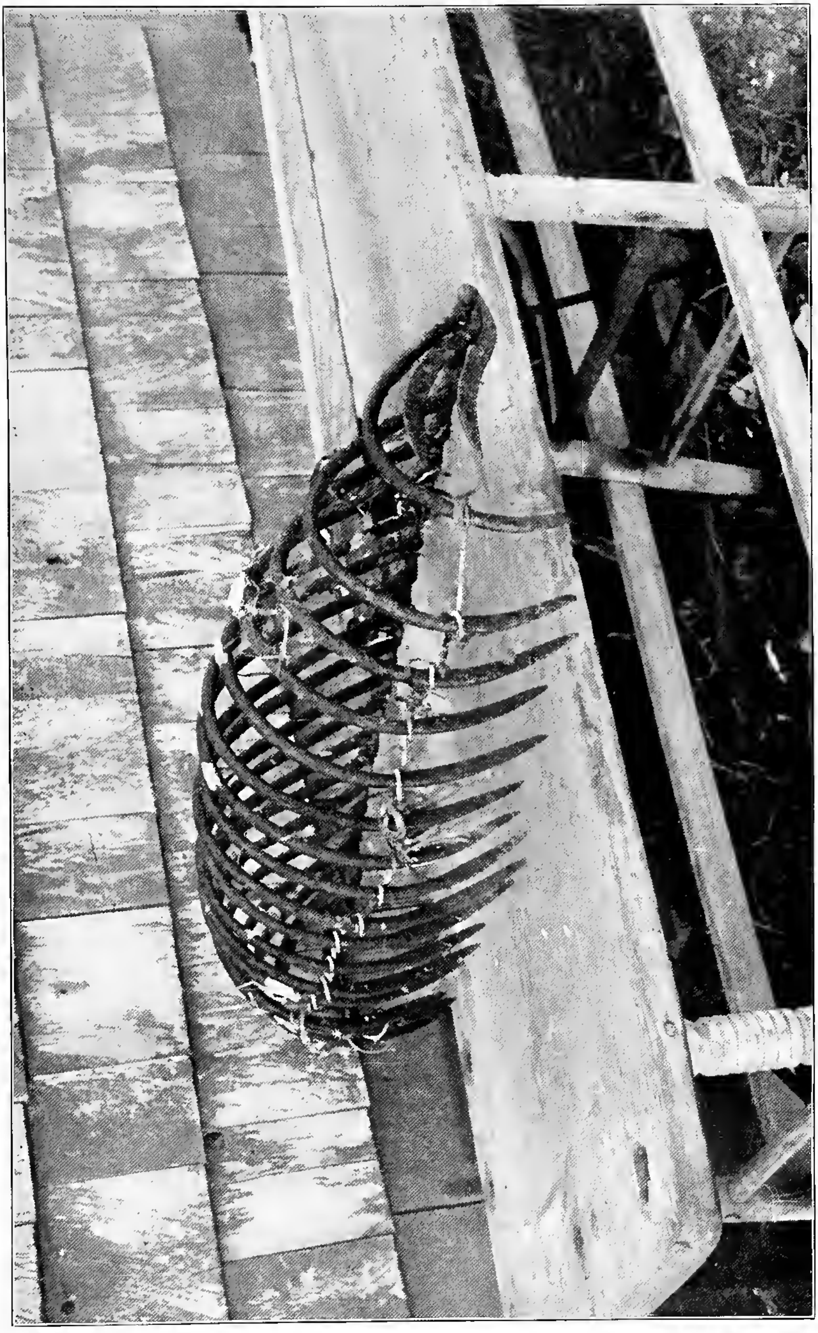
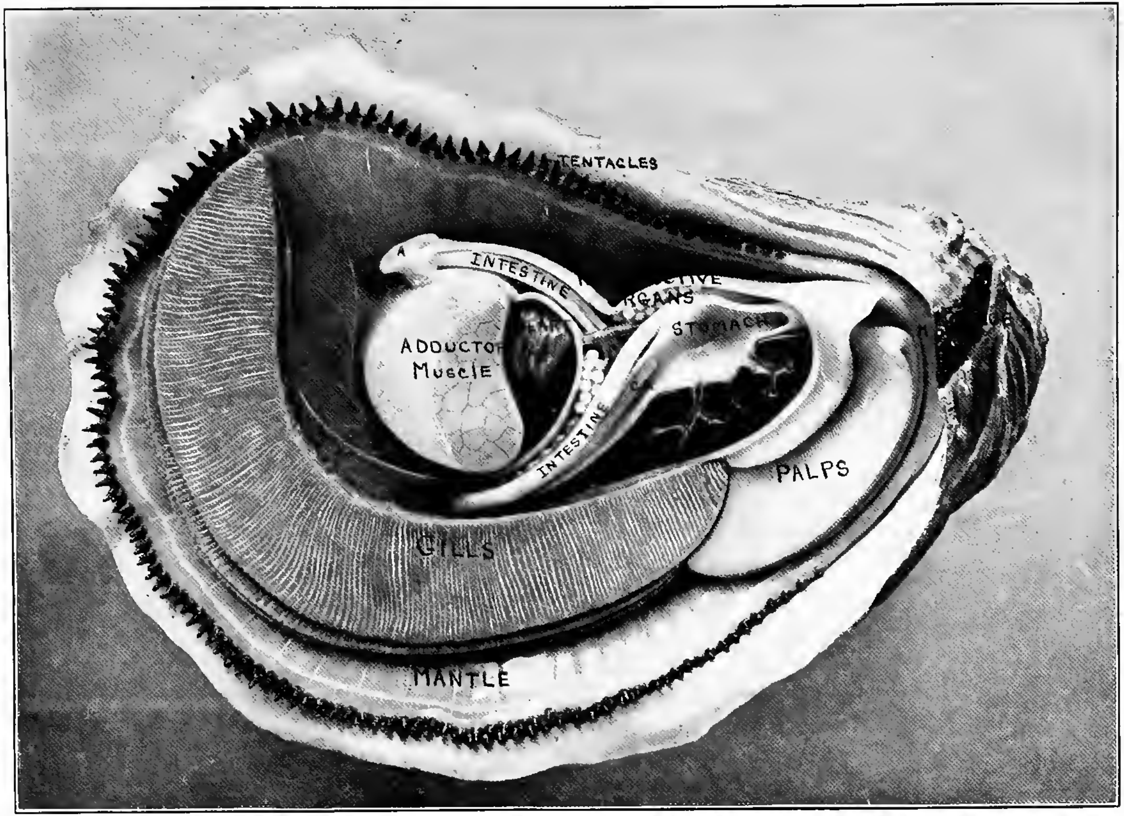


Fig. 61. — This style of basket rake is used at Edgartown and Nantucket. The whole rake is made of iron, no netting being required, as thin iron wires $\frac{1}{3}$ of an inch apart encircle lengthwise the entire basket, preventing the escape of any marketable quahaugs, while at the same time allowing mud and sand to wash out. This rake has 16 steel teeth, $1\frac{1}{2}$ inches long, fitted at intervals of 1 inch on the scraping bar. The depth of the basket is about 8 inches. Short poles not exceeding 30 feet in length are used, as the raking is carried on in water which does not exceed 25 feet in depth. Only the iron framework of the rake is shown.

Fig. 62. — Anatomy of the Oyster. — From a model in the American Museum of Natural History. The right valve and mantle have been removed to show the internal organs. The oyster may roughly be likened to a book, the valves of the shell representing the cover, the fleshy mantle closely lining the shell the first and last leaves, and the gills, running lengthwise beneath the large adductor muscle, the inner pages. Between the muscle and the hinge lies the heart, and above the gills the visceral mass, consisting of the cream-colored reproductive organs, which are here pictured as round white masses, and the dark-colored digestive organs. Between the anterior end of the gills and the hinge are the palps, four fleshy flaps, similar in appearance to the gills. The microscopic plants which form the food of the oyster are filtered out by the hairlike cilia of the gills, transferred to the palps, and passed into the mouth. A short œsophagus leads into the stomach, which is surrounded by a dark-green gland, the liver. The intestine passes backward, then folds on itself just below the adductor muscle, passes forward to form a second coil, before it again leads backward, to end above the heart and adductor muscle.


TENTACLES
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STOMACH
ADDUCTOR
Muscle
INTESTINE
PALPS
GILLS
MANTLE

Fig. 63. — The buildings of the Sea Coast Oyster Company at Wellfleet in 1910. The two boats lying at the wharf are typical gasolene oyster dredgers, by means of which the shells are put down for the capture of spat, the grounds are cleared, the seed is planted and the oysters gathered for market.

Fig. 64. — Herring River, Wellfleet, at low water, showing the shells planted for the capture of seed oysters in 1908 on the gravel bar north of Great Island. The shells and pebbles are covered with spat.

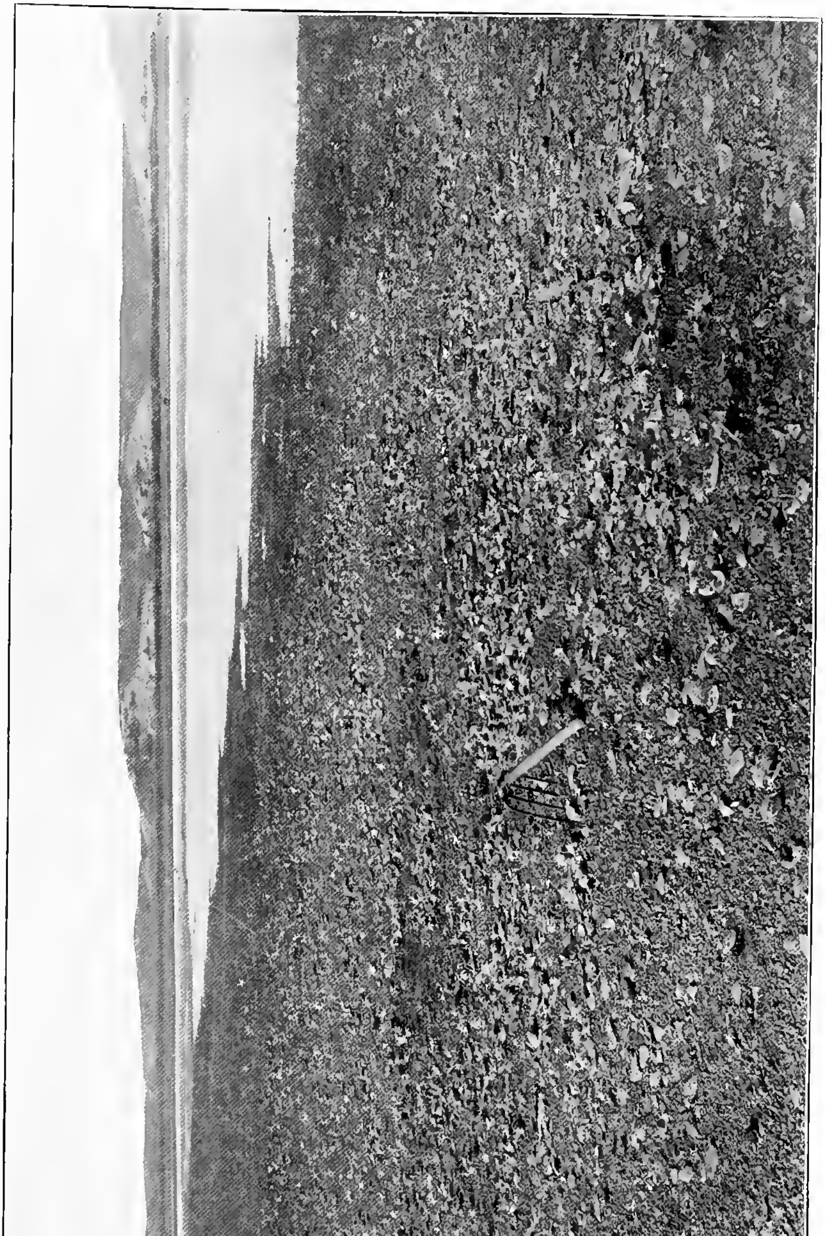

Fig. 65. — Near view of oyster shells on the gravel bar in Herring River. The set is about three months old. Notice the clean appearance of the shells.

Fig. 66. — Oyster seed, mostly two-year olds, attached to the wooden piles and the stones beneath Chequesset Inn wharf, Wellfleet, Mass. The abundance of the natural set on such objects indicates that successful spat collecting can be carried on in this locality. During severe winters the mortality is heavy, owing to the exposure between the tide lines; but these oysters have weathered two ordinary winters.

Fig. 67. — Oyster spat, one month old, on the shells of the experimental spat collectors located in Wellfleet Bay, 1908. Various shells, such as oyster, scallop, razor clam, clam, quahaug, silver or jingle shells can be utilized for spat collecting.

Fig. 68. — Figs. 1–20 illustrate the growth of the seed oysters caught on small stones. Figs. 1–10 show three-month-old oysters attached to living snails (*Littorina littorea*). Figs. 11–14 show the oysters of the same age attached to small stones. Figs. 15–18 show oysters one and one-half years old attached to small pebbles, while Figs. 19 and 20 show two and one-quarter-year-old oysters attached in the same fashion. Fig. 16 gives a peculiar illustration of the method of attachment. The young oyster has formed an attachment to a second pebble towards its free end at some distance from the first, indicating that the mantle, even at the age of one year, retains the power of secreting a fixative.

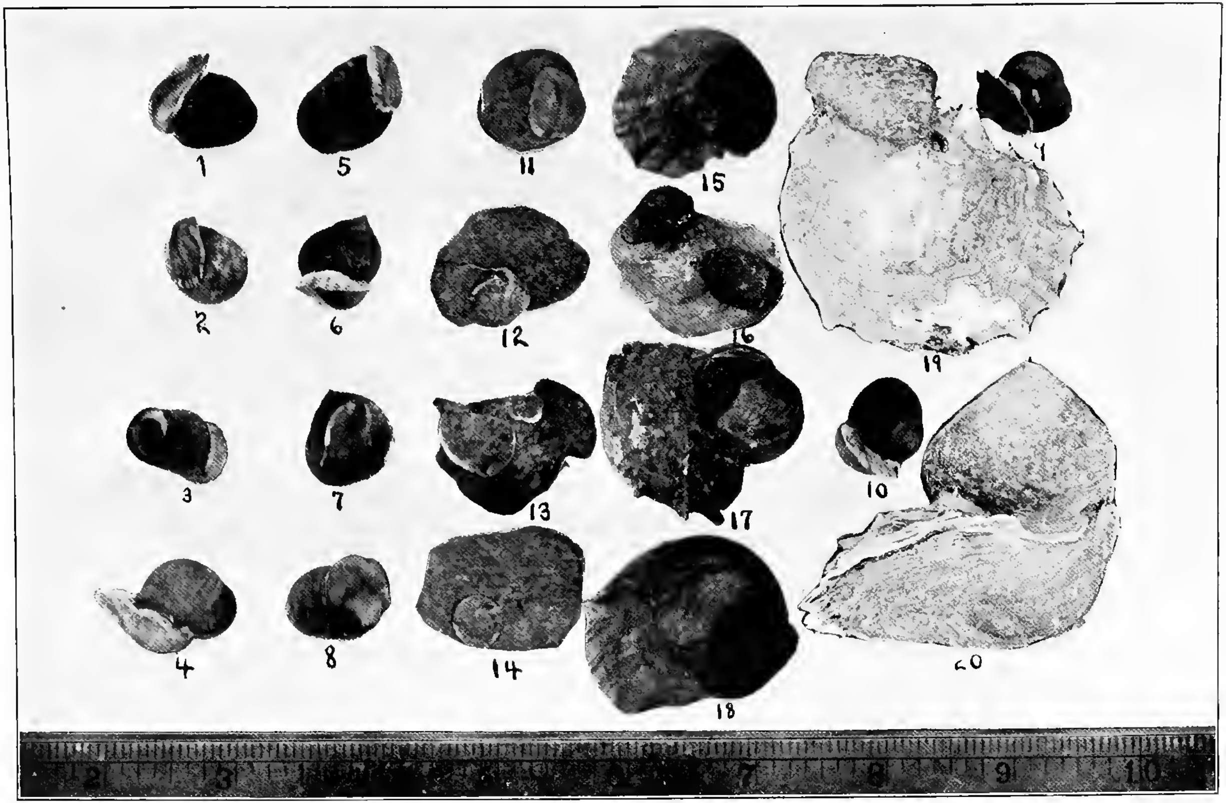
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Fig. 69. — Three-month-old spat upon stones, which were gathered beneath Chequesset Inn wharf, Wellfleet.